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The Development of Social Physics*

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1. The Increasing Interest in the Field: Alternative Titles

MY own fascination with the broader opportunities and responsibilities of natural scientists goes back to the early nineteen-twenties. Even then it had become clear that natural science and technology would continue their triumphant advances while social and humane studies, in order to reduce their tragic lag, would need to be equipped with methods far more effective than archaic types of merely verbal reasoning. With the untrammelled enthusiasm of a youthful Ph.D. in physics, I expected to find general sympathy with this program but the case was otherwise. There is a proverb that "In the country of the blind the one-eyed man is king," the falsity of which has been depicted in a story by H. G. Wells. One has to find for himself that in the country of the blind—meaning university faculties and their learned societies—the one-eyed man meets with lifted eyebrows.

The situation today is improving. Although academic patronage still remains in the hands of the specialists, to cross divisional boundaries is becoming respectable. The number of investigators whose scientific ideals were not satisfied with conventionally limited and piecemeal studies was not so minute as one had supposed. Now we are becoming aware of one another and we are glad to surrender our claims to individual uniqueness in return for the stimulus and support of association.

Norbert Wiener[1] has described the necessity and advantages of cutting across academic boundaries. Another investigator keenly aware of this, who began as a philologist before turning to what he likes to call "Empiric Social Science," is George Kingsley Zipf.[2] The joint fellowship program under the auspices of the National Research Council and the Social Science Research Council is of interest. These fellowships encourage a young physicist to acquire training in sociology, a sociologist in physics, and so on.

A notable little conference was held in Princeton October 12 and 13, 1949, with aid from The Rockefeller Foundation. Subjects included were mathematics, statistics, physics, astronomy, physiology, sociology, economics and marketing, philology, and history. This is the first public announcement of that conference and its findings, which may be interpreted as highly favorable to the broadening of the usefulness of research in the natural sciences by recognition of its relevance for organizing thought in the social sciences. Since it seems certain that a much larger group will find themselves in accord with us, the following statement is issued as a bench-

* Invited paper before The American Association of Physics Teachers, Brinckerhoff Theatre, Columbia University, Friday, February 3, 1950.

[1] Norbert Wiener, *Cybernetics* (Wiley, New York, 1948).
[2] George Kingsley Zipf, *Human behavior and the principle of least effort* (Addison-Wesley, Cambridge, 1949).

mark. It may strengthen the confidence of younger investigators interested in making new studies. The statement follows.——

Critical importance is attached to improved descriptions of social processes. No substantial body of social scientists is opposed to the collection of data which can be described in mathematical terms. No advocates among us were found for the idea that the study of human nature cannot be advanced by the same methods which have succeeded with physical nature. Mathematical reasoning about well-established social concepts supplements verbal reasoning or may even supplant it in some instances.

Modern mathematics is not limited to numerical equations, as is witnessed by such subjects as topology and theory of groups. Many students of the social sciences should be encouraged to familiarize themselves with the methods and some of the phenomena and principles of the mathematical sciences. The relationship is bilateral, in that wholly new phases of mathematics such as the theory of games[3] will be developed in order to deal more adequately with some types of social phenomena.

Standards of making and presenting social observations need to be raised in many cases. Difficulties of defining what is to be measured are even more evident than in the physical sciences, although the same difficulties are met in physics when high precision is demanded. There must always be a blur around the edges of a category when it is applied to phenomena. Wherever feasible some indication of uncertainties should be published with the observations; they are larger than most users of social statistics realize.

Some too-impatient applications of mathematical reasoning in the social field have tended to make unmathematical scholars accept its results with reservation. Perhaps as one example the idea of applying exact time cycles has been overworked. Valid empirical regularities occasionally have been pressed too far and employed as though they were complete theoretical explanations usable under conditions widely different from those where they had been proved to agree with observation.

The origination of social theories by the carry-over of analogs from the natural sciences requires special attention. An analogy even when detailed is not a proof but always must be tested against observed social data. The analogy must be more than verbal; it must express a function or abstract relationship which is common to the two fields. A question of terminology arises when such a transfer is made, but we are agreed that questions of mere names can be deferred.

The distinction between pure science and engineering exists also in the social field. There most workers have been interested in reaching decisions and making utilitarian application, as engineers, to a greater degree than in stopping, as scientists, with description and prediction.

Our discussions discovered and mapped an interesting rift between investigators trained in natural science and those trained in social science. There is a marked difference of opinion with respect to the usefulness of empirical regularity as a middle stage in progressing from observation to hypothesis or theory. While sociologists have given some attention to purely empirical studies, it is theory which has been the glamorous element. And social theory usually is elaborated deductively from considerations that have *a priori* appeal rather than from the much more laborious and detailed process of searching first for significant regularities among masses of observations—the search for regularity without regard to so-called meaning. One idea advanced in our discussions was that the conceptual level of the original observations must in some sense already be at the stage of final theory, and that in consequence the question always is, What observations to make? Which regularities will be significant?

We suggest that any natural scientist who may be ambitious to make a contribution to or criticism of social science should heed the red flags which came out in our discussions. Contrasts we touched upon, such as statistics *versus* history, communication *versus* uniqueness, denotation *versus* connotation, description *versus* decision, are not to be slurred over lightly.

We all feel that these results of only six hours of joint discussion among people who represent a wide scientific baseline is an encouraging preliminary test of the mixed-team method. Here is a new academic research tool. It was first proposed long ago, and under the name operations analysis has met with successes when directed toward engineering objectives.

Signers of this declaration of interdependence in research include: READ BAIN, *Miami University*, P. W. BRIDGMAN, *Harvard University*, REAVIS COX, *University of Pennsylvania*, WILLIAM J. CROZIER, *Harvard University*, STUART C. DODD, *University of Washington*, GEORGE A. LUNDBERG, *University of Washington*, OSKAR MORGENSTERN, *Princeton University*, MARSTON MORSE, *The Institute for Advanced Study*, JOHN Q. STEWART, *Princeton University*, JOSEPH R. STRAYER, *Princeton University*, JOSEPH L. WALSH, *Harvard University*, EDWIN B. WILSON, *Harvard University* (emeritus), MAX A. WOODBURY, *The Institute for Advanced Study*, and GEORGE K. ZIPF, *Harvard University*. It is a source of deep regret as well as pride to us that this was the last scientific meeting which Dr. Alfred J. Lotka attended. His death came before this pioneer in the mathematical study of society could comment on the results.

So much for the conference of last October. The term *Social Physics* does not occur in the statement. Other names for the same or allied areas already have been mentioned: Cybernetics,

[3] John von Neumann and Oskar Morgenstern, *The theory of games and economic behavior* (Princeton University Press, Princeton, 1947).

Empiric Social Science, and the very broad term Operations Analysis. One might add Political Arithmetic, Econometrics, Sociometrics. Some would refer to include the whole field under Statistics, and other suggestions have been made.

The name Social Physics is not a new coinage, but was suggested as long ago as 1836 by Quetelet (see below). August Comte used it for what we call Sociology. Florence Nightingale used it to mean Mathematical Statistics.[4] P. Sorokin[5] gives the impression that the name was common in the seventeenth century but does not quote any evidence; his account of "the mechanistic school" is unsympathetic. Indeed, his *a priori* definition of what constitutes "sociocultural phenomena" bars the physical approach from the beginning. But physics is physics wherever we find it.

Perhaps no special name at all is needed permanently. Meanwhile the name *Social Physics* has its own advantages. It calls attention of physicists to possibilities which mathematicians might overlook and it emphasizes the major significance of physical factors in social processes. Thus Dodd has listed time, distance, and numbers of people as among "the dimensions of society." Some derived quantities will be described in Sec. 4. The matter of attempting a formal definition of our subject is deferred until that point.

2. The Scientific Method

Innocent indeed is a physicist who thinks that the scientific method is so obvious as to need no description. This may have an element of truth as regards our own graduate students, because through experience they acquire a knowledge of "what must be learned but cannot be taught."[6] But if the method is to be exported to the social and the humane fields it will have to be taught, and first it will have to be formally described. Most of the Princeton conference was taken up by discussion of methodology. This had not been planned but the social scientists kept returning to it.

Many writers have attempted to describe the scientific method—physicists, biologists, philosophers, sociologists—and much that is sensible and much that is trivial has been written. This is not the occasion to attempt an adequate review of the extensive literature, but one warning must be uttered. No one should add to it without previously reducing his own naïveté by reading some of it.

The standard example of inductive progression, from the observations of Tycho through the empirical rules of Kepler to the theory of Newton which permitted correct general deductions, is not accepted by all writers as a pattern.[7] But to many of us it seems to form the principal mode of progress.

The physico-mathematical model is very much in the foreground now. I do not see any reason why the idea of the model is not easily included in the Tycho-Kepler-Newton fabric of inductive-deductive thought. Emphasis has been heavily shifted from the physics of the model to the mathematics since the days of the elastic-solid ether. Bridgman[8] in 1927 recognized the importance of Einstein's use of the mathematical framework or model, and in particular the emphasis this gave to operations rather than to definition by properties. E. U. Condon has given an excellent account:[9] "If we have really discovered the appropriate kind of mathematical framework for a given situation then the actual law of nature will usually be found to be the simplest of the various mathematical possibilities consistent with the known requirements." But this is analogy in the grand manner!

Leibniz was the great philosopher of analogy. He was a contemporary of Newton's, subtler than Newton, too subtle for that unprepared epoch. His influence is much less than Newton's partly because Leibniz had no friend like Edmund Halley to force him to write a *Principia*. Any group interested in unifying scholarship, in crossing divisional boundaries, must acknowledge—as Wiener does, although, it seems to me, not adequately—the leadership of Leibniz. In

[4] Helen M. Walker, *Studies in the history of statistical method* (Williams and Wilkins, Baltimore, 1929).

[5] Pitirim A. Sorokin, *Contemporary sociological theories* (Harper, New York, 1928).

[6] John H. Wolfenden, unpublished address.

[7] Morris R. Cohen, *Studies in philosophy and science* (Holt, New York, 1949); Hermann Weyl, *Philosophy of mathematics and natural science* (Princeton University Press, Princeton, 1949); Max Born, *Natural philosophy of cause and chance* (Clarendon Press, Oxford, 1949).

[8] P. W. Bridgman, *The logic of modern physics* (Macmillan, New York, 1927).

[9] E. U. Condon, *Am. J. Physics* **17**, 404–408 (1949).

the seventeenth century he tried to organize group scholarship and in his philosophy of monads he provided an apparatus for facilitating it.

He foresaw a generalized logic which should translate the concepts and relationships of one field into those of another by means of a vocabulary of equivalences. The monad reflects the universe; but there is an hierarchy of monads, and those of low degree reflect only obscurely. Arthur O. Lovejoy[10] has said: "Among the great philosophic systems of the seventeenth century it is in that of Leibniz that the conception of the Chain of Being is most conspicuous, most determinative, and most pervasive." Leibniz is called the father of symbolic logic but the mathematical logic of Boole, Russell, and Whitehead is scarcely a worthy descendent. It has not usefulness as "an instrument of research" that Leibniz planned. Indeed Leibniz's philosophy of a thoroughgoing unity is contrary to the conventional or Newtonian idea of a piecemeal learning which has no self-coordination.

"Hypotheses non fingo," said Newton, opponent of wide generality. When modern learning was still to be constructed, that turned out to be the correct practical attitude. Now we have a vast quantity of learning but so unorganized that most of it is unavailable at many of the points where it is needed. Success of the project which was the lifetime ambition of Newton's great and intuitive rival would provide the needed organization, through the discovery of a logic which should be at the same time a cataloguing system.

It took the engineers of the telephone company to make a fresh start toward what may in time become this modern logic. I refer to papers in the 1920's by H. Nyquist and R. V. L. Hartley and to the recent work of Shannon, which has been described in less mathematical form by Warren Weaver.[11] And, of course Wiener's "Cybernetics" is related to this. But one of the ideas is not so modern after all, because Francis Bacon[12] fully recognized that any information whatsoever can be conveyed in a "biliteral code," one which uses only two symbols. And this is in a book which has been called "the first great one on a secular subject in the English language." (Incidentally, C. E. K. Mees[13] remarked that Bacon was no experimenter. On the contrary, he was a prolific observer and experimenter although not a systematic one.)

The code is the thing for logicians to study because all knowledge must be coded. When the rules for formulating and translating codes are properly presented, I suggest we shall have an objective description of the inductive-deductive method. There is a prospect that the theory of codes relates closely to dimensional analysis in physics. In a senior paper in physics for the bachelor's degree in Princeton last spring, John W. Stewart, developing studies by Harry F. Olson,[14] showed that if energy, distance, and momentum, or again, energy, electric charge, and magnetic flux, are selected as fundamental dimensions, interesting isomorphism is displayed among the quantities and equations of mechanics, electricity, etc. This may be an indication of reduction to a single common code.

There is so much to be learned and taught in every special field that the achievement of a practical synthesis would seem to be impossible unless time for it is saved by improvements in the organization of what is already known. What Leibniz was looking for was, in a sense, merely a better filing system with easier cross-referencing. This point of view inevitably emphasizes analogy as an aid to research, without at all reducing the conventional and necessary emphasis on agreement between hypothesis and observation.

Physicists are used to quick tests by controlled experiments but astronomers, as well as social scientists, need patience to amass slow observations. In its present stage social physics offers for study no rigorous principles. Its known regularities apply only on the average to groups of people, and conditions are seldom controlled. Factor analysis in psychology is a blind mathe-

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[10] Arthur O. Lovejoy, *The great chain of being* (Harvard University Press, Cambridge, 1936).

[11] Claude E. Shannon and Warren Weaver, *The mathematical theory of communication* (University of Illinois Press, Urbana, 1949); see also Warren Weaver, *Scientific American* **181**, 11–15 (1949).

[12] Francis Bacon *The advancement of learning* (London, 1609), Book 6, Chap. 1.

[13] C. E. K. Mees, *The path of science* (Wiley, New York, 1946)—a fascinating book.

[14] Harry F. Olson, *Dynamical analogies* (Van Nostrand, New York, 1943).

matical process for indicating which are the leading quantities among all that might be listed as influencing a given situation. Physical science has got along by the method of successive approximations: One or two primary factors are discovered and allowed for, then the remaining discrepancies between hypothesis and observation are reduced by bringing in successively secondary and tertiary ones. But as Bridgman puts it, no holds are barred, and factor analysis may come to play a role in social physics.

3. Early History of Social Physics

John Graunt published his observations on the London bills of mortality in 1662, which established his position as a pioneer at one and the same time in social physics, social statistics, and demography.[15] He noticed the rough constancy year after year of deaths from certain specified causes, and of the ratio of male to female deaths. He compared rural and urban conditions and was able to estimate populations. To the year 1700 applications of mathematics in the social field were almost comparable with its applications in the physical sciences. But the appearance in 1687 of Newton's *Philosophiae Naturalis Principia Mathematica* raised thought in physical science to a plane of abstraction which even today social science has not achieved.

Then an amazing thing occurred: Primary mathematical development came for a long time almost to a halt in the social field, except for a while in France and Belgium. What activity there was consisted chiefly in the elaboration of leads already open in the 17th century. Let us, as an example, look at business mathematics.

Double-entry bookkeeping, which is still the foundation of accounting and still regarded as a difficult abstraction by many businessmen, had been invented in Italy before the year 1340. The ability of a bank to issue credits backed by only a fractional reserve was discovered in Amsterdam rather early in the seventeenth century, and the Bank of England was chartered in 1694. By that year Lloyd's coffee-house had become the rendezvous of underwriters of marine insurance; and fire insurance also was flourishing in England. Basic principles of life insurance and annuities were worked out by Edmund Halley, later Astronomer Royal, who published the first mortality table in 1693.[16] Joint-stock companies also began to be popular about that time.

This list, I think, covers the principal items of mathematical significance in modern business through the early 1900's. After 1700 there followed very important development in detail, particularly in actuarial science, but until quite recently there seem to have been no essentially new additions. Today business mathematics is again on the march. Mathematical statisticians like Walter Shewhart—another telephone engineer—have developed quality control which permits a great improvement in inspection practices for large-scale manufacturing. This represents a long-delayed impact of the Gauss error curve. Also with the current advent of input-output studies the discipline of econometrics at last is attacking major matters, supported by the possibilities of highspeed computing machines—and by grants from the Office of Naval Research. Marketing research also is having an active development.[17]

There had been a census of the inner wards of London in 1631 but the next census, of the whole city, was not until 1801. By then the practice of census taking, under government auspices, was rapidly spreading. A continually increasing volume of social statistics began to be collected, and this process is still being accelerated. Adolph Quetelet found that the Gaussian distribution curve had wide applications. He introduced the popular idea of the "average man" although warning his readers that the average man was an improbable being. He was deeply impressed by the approximate constancy year-after-year of the recurrence of odd happenings, such as murders by specified means. The empirical regularities in social statistics led him to the very important assertion: "It seems to me that that which relates to the human species, considered *en masse*, is of the order of physical facts; the greater the number of individuals the more the individual will is effaced. . . ."

[15] John Graunt, *Natural and political observations made upon the bills of mortality* ((reprinted by The Johns Hopkins Press, Baltimore, 1939), London, 1662).

[16] Edmund Halley, *Phil. Trans.* **17**, 596–610 (1693).

[17] Reavis Cox and Wroe Alderson, editors, *Theory in marketing* (Richard D. Irwin, Chicago, 1950).

He employed[18] the term *physique sociale* in the subtitle of his book, *Sur l'Homme*, published in 1836, on the title page of which is the following quotation from Laplace: "Let us apply to the political and moral sciences the method founded on observation and calculation, the method which has served us so well in the natural sciences." The collection of social statistics was one thing that the ideas of these astronomers encouraged.

Now we have huge masses and wide varieties of numerical statistics but most practitioners in the social field make little use of them, and what use they make is likely to be for *ad hoc* utilitarian purposes rather than general inductive study. In England the wonderful start which Graunt had made—a shopkeeper whose quality as a scientist was equal to that of any of his contemporaries in the Royal Society—was broadened immediately by Sir William Petty.[19] Petty's *Political Arithmetic* followed Graunt in recognizing and applying empirical regularities, although without enough observed statistics Petty had to be boldly speculative.

But in 1798 appeared the purely verbal suggestions of Thomas Malthus, who used physical terminology in a way which was *a priori* rather than operational. The historical criticism has been advanced by Lancelot Hogben[20] that the cloud of inky controversy aroused by Malthus's dictum, about limitation of the population by the food supply, blacked out for a long time afterward the avenue of advance which Graunt had opened. Now the increasing activity of demographers is a factor tending to turn more of the current of social thought into mathematical channels. Geographers also appreciate the desirability of making better use of the tremendous volume of geographical statistics.

Let us spare a glance at physics in the theory of government. The constitution of the United States is a document with significant physical aspects, fantastic as the statement may seem to hard-boiled laboratory men. It was created in 1787, just 100 years after publication of Newton's *Principia*, and its careful emphasis on division of governmental powers and on checks and balances among the agencies of government is a consequence of the influence of Newtonianism on its framers. For this assertion we have the authority of Woodrow Wilson.[21]

The Newtonian influence reached the founding fathers principally through the intermediary of the writings of Newton's elder contemporary and friend, the philosopher John Locke, and of Montesquieu in the mid-eighteenth century. To quote Wilson concerning the latter: "The admirable expositions of the 'Federalist' read like thoughtful applications of Montesquieu to the political needs and circumstances of America. They are full of theory of checks and balances. . . . Politics is turned into mechanics under his touch."

Thus the constitution of the United States had one important root in Newtonian mechanics. Until George Gallup, Doctor of Philosophy and advertising executive, began to make a business of public opinion polls about 1935 few advances of a mathematical nature occurred in the political field. The introduction of proportional representation might be cited as another bit of progress in applying mathematics to government—and some critics feel that both these innovations are of doubtful usefulness!

The mathematics involved in tables of weights and measures is too elementary for our notice, but so important a thing as a military table of organization uses scarcely more. In Caesar's legions three centuries constituted a maniple, two maniples made a cohort, ten cohorts a legion, and there seems to have been even then a distinction between line and staff. Business tables of organization as well as military ones have not changed since in any major way, although the role of the staff is better recognized and the chain of command is not always so simple.

There is space for only two more names in this very abbreviated history. Henry C. Carey, self-educated publisher of Philadelphia retired at the age of forty-one from a successful publishing business to write about social science. He wrote

[18] Adolphe Quetelet, *Sur l'homme* (Louis Hauman & Company, Brussels, 1836). Frank H. Hankins, *Adolphe Quetelet as statistician* (New York, 1908).

[19] Sir William Petty, *Several essays in political arithmetic* (London, 1699).

[20] Lancelot Hogben, editor, *Political arithmetic* (George Allen and Unwin, Ltd., London, 1938).

[21] Woodrow Wilson, *Constitutional government in the United States* (Columbia University Press, New York, 1908).

with acuteness and originality but tiresome prolixity; his three-volume *Principles of Social Science* appeared in 1859. Carey interpreted social phenomena as natural phenomena surrounded on all sides by other natural phenomena. He examined whatever social statistics he could find and in his travels he looked at country and people. His early writings were respectful toward the British school of Malthus, Riccardo, and John Stuart Mill, but he came to distrust and bitterly oppose their dismal dicta. He began to emphasize numbers of people and their distances apart as social factors of great significance. He described the advantages which people gain by mutual association when many of them live close together. Thus he clearly anticipated the hypothesis of demographic gravitation which will be described below, and even used the term "molecular gravitation" as applying among people.

Unlike his bookish contemporary, Karl Marx, the practical Carey ninety years ago foresaw an exciting future for productive enterprise, based on cooperation of employer and employed, on improving technology, and on continued population growth.

It is not generally known, even among astronomers, that Simon Newcomb, who at the turn of the century was the leading world authority on celestial mechanics, was the author of a full-fledged text of economics.[22] In the preface he wrote of economics that "nothing is needed to give the subject a recognized place among the sciences except to treat and develop it as a science. Of course this can be done only by men trained in the work of scientific research and at the same time conscious of the psychological basis on which economic doctrine must rest." Unfortunately he gave the *a priori* psychology and doctrine far greater emphasis than new empirical studies which he might have developed more fully. Apparently a little ashamed of his departure from orthodox specialization he gave his work in economics minimum mention in his autobiography.

In closing this section we may ask ourselves, What conclusion is suggested by the fact that seventeenth-century activity in applying mathematics in social science was not followed through with enthusiasm in later years? Is it not possible that the reason was overspecialization? Newton's profound successes drew physical and mathematical talent into problems of matter and away from problems of man. With the rapid growth of information the universities everywhere were swallowed by their own departments. Academic leaders, believing that practical unity of knowledge was gone forever, agreed with one another to partition off little spaces within which each could indulge the human passion for empire building, albeit in a minor way. This partitioning of research left the problems of man to be dealt with on the campuses by industrious scholars who were insulated from the logic which was making the modern world. Innovations such as Carey's, Gallup's, Shewhart's, and Shannon's came from outside ivied halls.

4. Recent Research

If a tentative definition of social physics is required, the suggestion already quoted may be taken as a guide—that the dimensions of society are analogous to the physical dimensions and include numbers of people, distance, and time. Social physics deals with observations, processes, and relations in these terms. The distinction between it and mathematical statistics is no more difficult to draw than for certain other phases of physics. The distinction between social physics and sociology is the avoidance of subjective descriptions in the former.

Since people can be classified in various ways according to objective tests, there must be additional dimensions, just as electrical and magnetic phenomena cannot be dealt with in terms of mass, distance, and time only. What these may be remain to be found; one speculative suggestion is mentioned below.

There is no immediate necessity for bringing all objectively measurable social quantities into this system, whatever ambitions individual investigators may entertain for the future.

A relation only to time is not enough to tag a process as physical, but perhaps we can agree tentatively that any measurable phenomenon which involves number of people and either distance or time, or both, is within the scope of social physics.

[22] Simon Newcomb, *Principles of political economy* (Harper, New York, 1886).

As a first example of a problem in social physics, take the representation of a population P as a function of time t. Two of the three mentioned dimensions are present. In many cases the so-called logistic, a merely empirical formula

$$P=P_1+\frac{P_2-P_1}{1+be^{-at}} \tag{1}$$

gives a fair fit—if suitable choice is made of the four parameters, P_1, P_2, a, and b. Obviously P_1 is the population a long time ago and P_2 will be the population in the far future.

The work of Raymond Pearl and L. J. Reed[23] with this formula is well known. Their prediction after the census of 1910 of what the United States population would be in 1950 was better than demographers were making only half a dozen years ago. At first Pearl thought this formula was a "law" of biology.

A number of papers have been published by Hornell Hart[24] who has applied the logistic to a variety of social statistics. He found in some cases that it was necessary to represent the observed growth by two successive logistics. A discontinuous change in the parameters from one to the other occurs at an unpredictable time. In an unpublished study, W. F. Sutherland (of the Toronto Hydro-Electric System) has examined the conditions under which the variation of current or voltage with time in an electric circuit would follow curves similar to the logistic. When the variation of economic activity is so examined he can tentatively define and evaluate "economotive force," "economic resistance," and the like. The degree of usefulness of such an interpretation in various cases where the logistic describes the growth remains to be seen.

Palmer Putnam of Southwest Harbor, Maine, in an as yet unpublished study of estimates of the total human population in the world since the earliest times, finds that the second difference passed a maximum several centuries ago and, while still positive, is slowly decreasing. If the second differences are plotted against time and smoothed a continuation of the current rapid growth of world population is indicated, with a value of ten billions suggested about 2100. This is merely an empirical extrapolation, but that a lot more people will join us is highly probable unless the military engineers turn the planet into a temporary star. Numbers in the billions lack effective meaning except to mathematical scientists. An alternative method of predicting world population, preferred by demographers, is to project specific physical factors—birthrates, deathrates, family sizes, estimates of food supply —country by country, but at the stage where all these uncertain estimates are assembled to form a total one doubts if reliability of prediction is increased. The extrapolation mentioned suggests a world population of about 3.6 billions in the year 2000 and 5.8 billions in 2050.

Application of exact time cycles to social data on an empirical basis has interested very many people.[25] The method of periodic cycles applies in physics to musical notes, light, radio, and tides, but has uniformly failed with sunspots. In economics the business cycle is notorious and so far has been unpredictable.

An empirical on-the-average relation of a different sort is furnished by the so-called rank-size rules. Pareto's "law" of distribution of incomes is one example. Rank-size rules are featured by Zipf: See also Harold T. Davis.[26] The general rule is

$$R^nS=M, \tag{2}$$

where n and M are constants for a given series and S is the size of the Rth number of the series. The rank R is 1 for the largest member, which has size M.

For incomes before deduction of taxes in various countries at various times, n approximates 0.5. For cities greater than 2500 population in the United States at every one of the sixteen censuses 1790–1940, n has been unity. For cities in Europe it slowly increased from about 0.7 in 1725 to 0.82 by 1870, and then remained constant as shown in Fig. 1. For Japanese cities it increased to about unity during the decades of industrialization before 1941. For acreage in farms bigger than 50 acres in the United States n was 0.76 in 1945. For counts of words in a vocabulary ranked according to frequency of use, n often is unity.

[23] Raymond Pearl and L. J. Reed, *Studies in human biology* (Williams and Wilkins, Baltimore, 1924).
[24] Hornell Hart, *Am. J. of Sociology* **50**, 337–352 (1945).
[25] Edward R. Dewey, *Cycles* (Holt, New York, 1949).
[26] Harold T. Davis, *The theory of econometrics* (Principia Press, Bloomington, 1941).

The rank-size rule is very different from the distribution functions familiar to statisticians such as the Gaussian, and in many cases fails to hold below a threshold size, as for villages when cities are ranked. The existence of a threshold suggests that the same sort of factors are at work as when waterdrops are formed in water vapor. Drops smaller than a certain size are in unstable equilibrium and do not grow when the larger ones do. Thus in a vocabulary the existence of a word implies that its meaning is required frequently enough to justify its coinage.

In the United States there has been an empirical relation between the area A of a city and its population P on the average

$$A = P^{\frac{3}{4}}/b, \tag{3}$$

where, as Fig. 2 shows, the constant b was about 357 in 1940, and 400 in 1890.

Western and southern cities tend to have bigger areas than those of the same population nearer New York. This observation fits with others which suggest that the rural population can be treated as a gas, and cities as condensations of the "human molecules." If the rural gas in the environs of a city is at a relatively low density, as it is for the western cities, the condensation can swell somewhat, not being as fixed in size as a waterdrop.

Another empirical formula we have found at Princeton relates the urban fraction of United States population to the number of cities, which increased from 24 in 1790 to 3464 in 1940 while the urban fraction was rising from 5.1 percent to 56.5 percent. This is another indication that a rural-urban equilibrium of a physical type exists.

It may be claimed for the subject of demographic gravitation that it has passed beyond the stage of empirical regularity to that of a synthetic theory, from which if care is employed reasonably secure deductions can be made. This entire paper could have been devoted to it.[27] The same equations apply as for physical gravitation, but with appropriate changes in meaning of the concepts. Thus the "demographic energy" E associated with the mutual gravitation of two populations N_1, N_2 spaced a distance d_{12} apart is

$$E = \frac{G(\mu_1 N_1)(\mu_2 N_2)}{d_{12}}, \tag{4}$$

where G is a constant, and μ_1, μ_2, the "molecular weights," are also constants for the particular sort of people. The weight unity is chosen for the average resident of 28 states from Texas to Maine, excluding states of the Deep South as well as Rocky Mountain and West Coast states.

A variety of observable "interactances" (the term is S. C. Dodd's) between two populations are observed to be roughly proportional to E. One instance is the interchange of telephone calls. If on a map a straight line is drawn connecting P_1 and P_2 and showing by its breadth or otherwise the magnitude of the computed E it is called a "desire line." The name was adopted as long ago as the early 1930's by highway traffic engineers for a line connecting two points or areas and representing the amount of motor traffic originating in one with destination in the other, as determined, not by Eq. (4) which was not known and does not apply at short distances, but by sample "O and D" counts on the highways.

In many instances (cf. Fig. 3), such as the study of number of students residing in a particular state who attend a "national" college like Princeton or Vassar, or a school like Exeter or Lawrenceville, it is convenient to compute V_2, the "potential" of a state's population P_2 at the geographical place of the college:

$$V_2 = \frac{G\mu_2 P_2}{d_{12}}. \tag{5}$$

The number of students from the given state is observed to be on the average proportional to the potential of population of that state at the campus.

Many maps such as Fig. 4 showing approximate contours of equipotential have been made requiring only census data of populations, and Thomas B. Bissett[28] built a little machine to draw them. Certain statistical quantities, such as rural densities and farmland value per acre, have been shown to be constant on the average

[27] John Q. Stewart, *Theory in marketing* (Richard D. Irwin, Chicago, 1950), Chap. 2.

[28] Thomas B. Bissett, *ibid.*

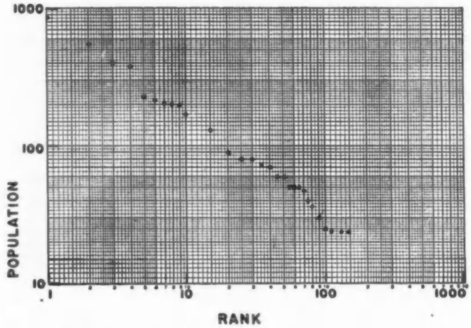


FIG. 1. Rank-Size Diagram for Cities of Europe about 1800. The populations, with 000 omitted, are plotted on log-log scale as ordinates and the ranks as abscissae, i.e., London, 1, Paris, 2, Constantinople, 3, and so on to York, England, 145. All cities, including those in European Russia, above roughly 24,000 population are included, according to data given by John Pinkerton, *Modern Geography*, Vol. I, London, 1802. Most of his populations are precensus estimates and are not individually reliable, but for London and Paris the populations of their first census (1801) have been plotted. The leading 10 cities are individually shown but only every 5th or 10th of the remaining ones. The negative slope is about $n=0.73$, Eq. (4). This little study has not previously been published.

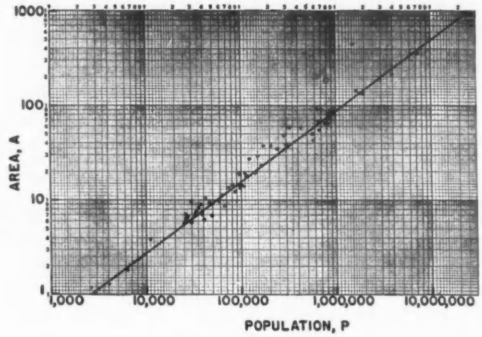


FIG. 2. Average Relation of Area to Population for U. S. Cities, 1940. On log-log scale the land area in square miles of each city is plotted as ordinate and its population as abscissa, both from the Sixteenth Census, 1940. The leading 15 cities are shown individually; Los Angeles and New Orleans each has much more than a "normal" area. The remaining 397 cities larger than 25,000 are represented in the plot by successive medians of five cities (to rank 105), then of groups of 15. In addition 5 more sample medians are shown for 11, 11, 11, 41, 41 small cities, down to population 2500, the rural limit. The smoothing by medians suppresses the full range of individual deviations. The areas are the "political" areas within the official city limits, excluding water, which makes little difference on the average. In some cases the "physical" area—for which data in general are unavailable—would be larger, in others smaller. Equation (2) holds also for the relation of areas to populations of the 140 metropolitan districts listed in the census for all cities above 50,000, but for these the divisor in the formula is only 45 instead of 357. This diagram has not been published before.

along a given equipotential and to be about proportional to some power of the potential. The empirical on-the-average rule that the rural density is proportional to the square of the potential has held in the United States at least since 1840, and in Europe in the 1930's and even in Mexico (cf. Fig. 5).

Studies by several investigators have shown that the following are among the social quantities which to a first rough approximation are functions either of potential of population or of demographic energy.

Attendance at seasoned "national" colleges and schools and at major fairs, etc.
Long distance telephone calls.
Long distance passenger automobile traffic.
Long distance rail and bus passenger traffic.
Interregional flow of bank checks and postal money orders.
Newspaper circulation at a distance.
News items, by city date lines.
Newspaper obituaries, by city date lines.
Density of various components of the population in rural regions.
Rural nonfarm rent.
Farmland value per acre.
Rural deathrate.
Miles of highway and railway per square mile in rural regions.
Pedestrian traffic within a city.
Marriages of couples who both resided in the same city.

Correlation coefficients have been computed in many instances and tend to be from 0.70 to 0.90 with none below 0.50. A few least-squares solutions have been made also and are satisfactory.

For example, the density of wage-earners in manufacturing who reside in rural areas rises steeply with the potential of population across the United States, about as the fifth power, while the density of farmers increases very roughly as the first power of potential. These data can be interpreted in terms of an astrophysical model of Emden and Eddington—a cloud of gas which is under the influence of its own gravitational field. Temperature and density increase toward the center. Temperature is proportional to the first power of the gravita-

tional potential, but the density may vary as some other power, depending on the "polytrope."

When residential rent, or the density of motor traffic, or the like within a city is compared with the same quantity in the rural environs it is found that the increase within a city of small or moderate size is greater than would be expected from the increase of population potential there as shown in Fig. 6. To account for this we assume an extra energy of "cohesion" within the city. Cities usually have rather sharp-edged boundaries; the population density falls from thousands per square mile to scores often within a distance of a few hundred yards. The presence of cohesion is independently indicated by this fact.

Within a city a standard pattern of density increase toward the center is indicated when an average is taken of several cities. Just as formula (3) shows a proportionality of mean density P/A to the fourth root of the population P, another regularity exists with respect to the central peak of density, which for a large city is many times the mean density.

Finally, the total annual income of the residents of a given district in the United States is found to be roughly proportional to the sum of the gravitational and cohesional energies. The national income for as far back as the data run, say from 1829, increased to 1940 in proportion to the total demographic energy, by a factor of about 75. Two Americans a mile apart contributed on the average a quarter of a cent per year to the national income, but this figure fluctuated with the business cycle, rising in the booms and falling in the panics. The "unit of demographic energy" is two standard people at unit distance.

Edith Bissett, an associate, made a preliminary study also of the kinetic energy K defined by the formula

$$K = Fhu, \tag{6}$$

where F is the mass of artificial goods moved per unit time, h is its average length of haul, and u is its average speed from origin to destination.

One emphatic conclusion of social physics is that the physical mass, and the mobility of this mass, required for civilization is tremendous. If not only the roadbeds of highways and railways are included but also water behind dams and in reservoirs—and New York is learning now how important water is—the mass of artificial goods per capita in the United States runs to many hundreds of tons.

The suggestion is not without merit that the weighting factor applied to people in the equa-

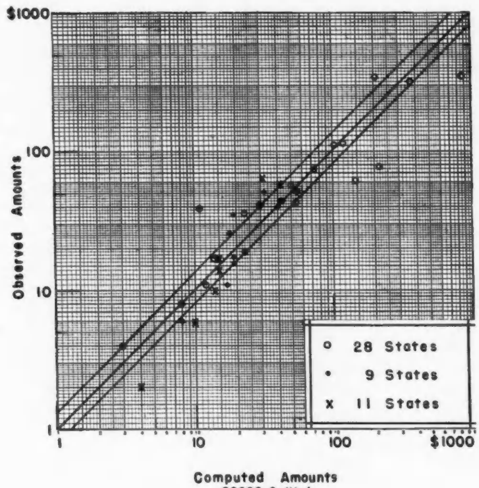


FIG. 3. The Flow of Bank Checks into New York. The numerical data of this graph were published in *Theory in Marketing*, Chapter 2 (see footnote 17), based on information kindly furnished by Messrs. R. W. Scheffer and H. D. Crosse of the New York Federal Reserve Bank. Each of the thirty-four branches outside New York City of the Federal Reserve System is represented by a point, differentiated in accordance with its location in the areas Texas-Maine (twenty-eight states), Deep South (nine states), Far West (eleven states). The respective "molecular weights" μ indicated by this and similar studies are 1 (the assumed standard), 0.8, 2. The total dollar value of checks returned for collection by airfreight each full business day is plotted as ordinate. The corresponding abscissa is the computed amount, obtained by multiplying the potential of population of the branch district at New York (Eq. (5) with $G=1$ and d in miles) by 850—this constant being an adjustable parameter determined to fit these particular data. Thus 10,000 "standard" people living 1000 miles from New York would account per day for a payment to New York of $(10{,}000/1000)\times 850$, or \$8500.

The data are from a sample count of checks made for the twenty-one full business days in October 1948, and represent payments by check from the rest of the United States to New York, totalling 4.64 billion dollars for the month—an important sample of our business linkages. The large discrepancy for Philadelphia (upper right) doubtless is at least in part because airfreight was not used for most of the checks returned for collection over its short distance. Further study of all the discrepancies would be worthwhile. Agreement of observations with a formula to within a factor of 4 to 3 in half the cases is about all we expect in any first approximation in social physics.

Presumably the same sort of geographical distribution would be found if we had similar data for banking centers other than New York. The indication is that on the average each standard person sends to each of the others payments by check averaging per year 2.8 cents divided by their mutual distance in miles.

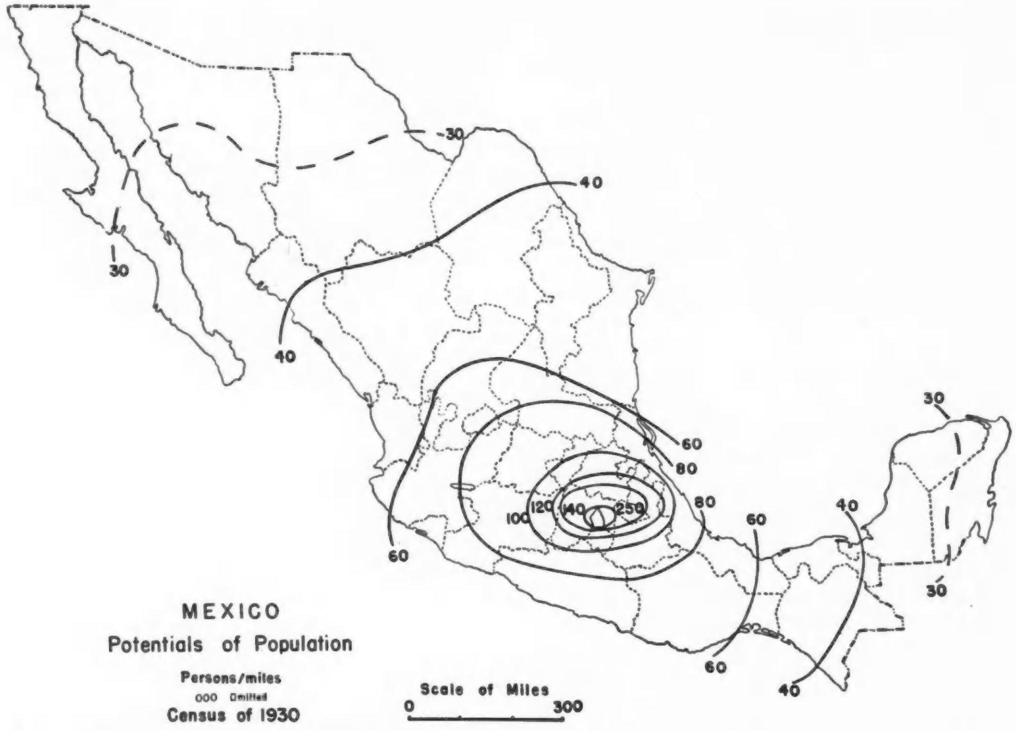


FIG. 4. Potentials of Population in Mexico. This map, by James K. Meritt and Edith Bissett, was computed from the Mexican census of 1930. The peak, above 250,000 persons per mile, is at Mexico City. Comparison with similar maps (*Geographical Review* **37**, 461–485 (1947)) reveals that this is the only instance where a major human concentration (United States, Europe, etc.) has its highest potential at an *inland* city. Of course every city is a local peak, but a more laborious computation is required to show such details.

tions of demographic gravitation is proportional to the available mass of goods per capita. This would give the inhabitants of India and China relatively small molecular weights, in agreement with the low level of sociological interactance there—which is low notwithstanding the proximity of hundreds of millions of people.

The coexistence of the kinetic energy of Eq. (6) and the potential energy of Eq. (5) suggests introducing the virial theorem of Clausius, as applied by Poincaré to a cluster of gravitating bodies in interstellar space. When the kinetic energy is relatively large the swarm will tend to expand. The people of the United States have been pushing to the west since their beginning. The slow western movement of the arbitrary center of gravity published by the Bureau of the Census is a less suitable measure of this expansion than is the root mean square of the distance of people from New York City. This rose from 340 miles in 1790 to 1030 miles in 1940 and is greater now. New York has been the major potential peak of the country for over a century—and therefore the sociological center.

This rapid and summary review by no means exhausts even the matters we have studied in Princeton, and there is much being done by others.[29] Studies of highway traffic already have been mentioned as amenable to mathematical analysis; we have in our files memoranda recently prepared by W. R. Bellis of the New Jersey State Highway Department. An interesting geometrical rule has been found by Philip Kissam of the

[29] Louis I. Dublin, editor, "The American People," Philadelphia, *The Annals of the American Academy of Political and Social Science*, Vol. **188**, November, 1936; N. Rachevsky, *The mathematical theory of human relations* (Principia Press, Bloomington, 1947); Harold Hotelling, *Econometrica* **17**, 66–68 (1949).

Department of Civil Engineering in Princeton, and John Tukey of the Department of Mathematics, to the effect that if straight lines connect in pairs a random group of points, the total number of their intersections increases as the fourth power of the number of points. Consequently traffic jams occur in cities! Important surveys are made by psychologists and social psychologists.[30] Educational testing also is a prolific field.

The speculative relation to magnetism promised at the beginning of this section is that Curie's law may have a parallel in the effect of propaganda. A paramagnetic substance under the influence of a given magnetic field H will become magnetized in direct proportion to H and inversely as the absolute temperature T. Similarly some observations made by the research staff of *Time Magazine*[31] may be interpreted as suggesting that in areas of relatively high popu-

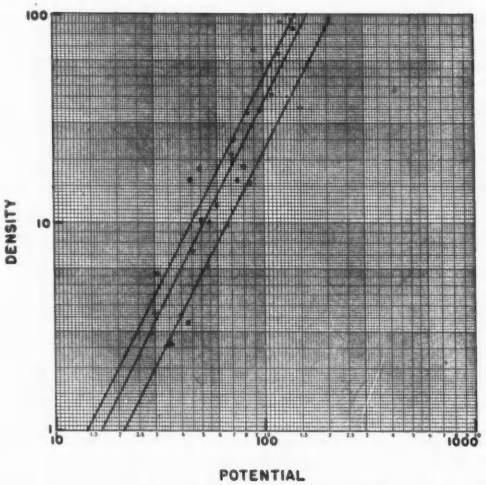


FIG. 5. Relation of the Density of Rural Population to the Population Potential, in Mexico. This graph on log-log scale applies to the census of 1930. This study has not been published before. Each plotted point represents one of the states, the potentials (abscissae) being read from the map of Fig. 4. The central line is the median line having a slope chosen as 2:1 (rural density varying as square of potential), while the outer two lines subdivide each half of the observed points into quarters. Three additional states so counted are not shown because a large reduction in scale of the diagram would be required: namely, Distrito Federal, potential roughly 280,000 persons/mile, rural density 165 persons/square mile; Quintana Roo, 25,000, 0.41; Baja California, 20,000, 0.89.

[30] Samuel Stouffer and others, *The American soldier* (Princeton University Press, Princeton, 1949).

[31] Frank A. Stewart, *Sociometry* **10**, 11–31 (1947).

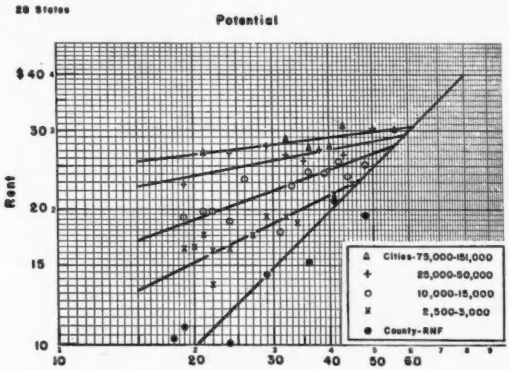


FIG. 6. Relation of Residential Rents to Potential of Population. Rents in dollars per month per dwelling unit are from the U. S. Census of 1940. Medians for groups of cities are plotted. The region represented is the Maine-Texas sequence of 28 states. A given size of city tends to have higher rent if in a part of the country where the general potential of population is high (before inclusion of the city's own contribution locally to potential). The black disks represent rural nonfarm residential rent, being medians for groups of completely rural counties. Rural nonfarm rent tends to increase as the first power of potential. The rise from country to small cities in the same neighborhood is an indication of "cohesion" in the latter. Evidently this tends to decrease at high potentials—just as the latent heat of evaporation in physics decreases at the higher temperatures. The abscissae are rural potentials in persons/mile with 0000 omitted.

The same sort of families of curves represent urban taxes per capita, areas of cities, etc.

lation potential a smaller percentage of the residents tend to be aware of local social information of a given degree of significance. (As already has been indicated the "rural gas" may be thought of as having a "temperature" in proportion to its population potential.)

This account of selected recent research and trends is far from complete but may serve to give the reader an idea of possibilities.

5. Some Areas of Utilitarian Application

In any new subject which has practical uses engineering and science tend to be intermingled, E. B. Wilson has said. Principles such as that of demographic gravitation need to be supplemented by various refinements under the test of practical demands. Social engineering is a term which has been coined by many independent writers. It can be defined as the application for utilitarian purposes of the findings of social physics.

The current limitation of the latter to on-the-

average regularities is less disadvantageous for the descriptive science than for the engineering. Only an enterprise big enough to give the average an operational meaning stands to profit by adjusting to it. However, many people become interested in something only when it promises practical results; here are a few suggestions for development.

Consider local and regional planning. Because observation shows the existence of on-the-average regularities in the rural and urban distribution of population, any master plan which does not conform to that average implies the application of special constraints on the people. In many cases a natural constraint exists and changes the standard pattern, often in a known way: For example, lakeside cities tend to be not circular but semiellipses elongated on the lake shore, as though they adhered to it. Highways leading out from any town are likely to be lined for some distance with rural nonfarm dwelling houses having open fields behind, reminding a social physicist of the rise of liquid in a capillary tube.

Planning in some of its phases is by no means new in economic geography where theory of location long has engaged attention.[32] Demographic gravitation makes for centralization, the piling up of people toward the metropolis. The principal decentralizing tendencies are (a) cohesion and adhesion, which bind people at some particular spot; and (b) easy transportation of goods and passengers, which may have an expanding effect like heat.

In the old days of walled cities, military defense no doubt exercised a centralizing tendency, but now the talk is of dispersal. Some outrageously impractical suggestions have been made toward dispersing industry in this country. Threatened loss of key factories aroused the governors of peripheral states, and last November the Secretary of Defense assured the New England Council that only local dispersal was being advised.

I must confess to being at a loss as to what the counterpart process in physics is that would bring about either an aggregation or a dispersal of molecules which would result in avoidance or attainment of some effect in the future. This brings up an educational value which social physics possesses, namely that it aids in describing social processes in an objective way. The vital need of the social studies is better agreement, better coordination, a central nucleus of fact and relation accepted by the great majority of experts. Indications are that this cannot be realized without bringing demography, economics, and political theory into close relationship. A physical model can suggest a preliminary common terminology which is at least definite.

Adequate development of the demographic model of the gravitating population ought to answer such a question as, What will be the long-term effect of subsidizing a low potential area by transfer of funds raised by taxing residents of areas where the population potential is high? Federal aid for schools is such a project. Before the doctrine of the conservation of energy was established perpetual motion was a goal of inventors, but secondary and tertiary reactions which were overlooked in the design of a given machine always defeated its plausible primary operation. There are sentimental social reformers who resemble those misguided inventors. If application of new funds in backward areas liberates there new social energies sufficient to recompense the original taxpayers there can be no question of the success of the subsidy. Such a problem has important quantitative elements which enthusiasts trained only in qualities are likely to ignore—to the downfall of the economy and the oppression of the prudent.

As another example of a problem for study, consider the statistics recently publicized by the Secretary of Commerce showing that in certain manufactures most of the production is carried on by a small fraction of all the companies. This is merely another instance of the pervasive rank-size rule. So the question is, How big an exponent n, in Eq. (2) constitutes monopoly? With n unity, 2 percent of all the United States cities house 50 percent of the urban population. Does this represent unfair competition in restraint of trade?

Again, if before-taxes incomes in a free-enterprise economy "naturally" follow a distribution having $n=0.5$, might not a graduation of income taxes be desirable which after taxes kept the rank-size distribution but with n reduced to some smaller value, such as 0.4? Again, for cities in

[32] Edgar M. Hoover, *The location of economic activity* (McGraw-Hill, New York, 1948).

India and Pakistan n was 0.78 in 1941 before the separation.[33] If the two governments build the new frontier into a serious barrier, no doubt in time the distribution will be modified, with heavy consequences for the principal cities.

To a physicist much standard statistics seem only a beginning. Pareto's law has been known, to a few scholars at least, for many years; but statisticians often are satisfied with a purely formal description instead of advancing to operational manipulation. Witness the Census Bureau's almost meaningless "center of United States population," on vacant farmland in Indiana.

Merle Tuve, widely honored for his leadership in developing the proximity fuse, has declared that natural science is one of the humanities.[34]

[33] V. K. K. Menon, *Science and Culture*, Calcutta, **15**, 135–138 (1949).

[34] Merle Tuve, address at the Princeton Graduate School, December 30, 1949.

This is true. But people are being led to believe that natural science exists chiefly as an adjunct to military engineering and as the producer of useful gadgets. Perhaps there are a very few laboratory physicists who are satisfied with so limited an outlook, but most scientists have supposed they were devoting their lives to something more.

The experience of two world wars indicates that defense by material agencies, although it seems to be necessary to preserve our hundreds of tons per capita of metal, paper, water, stone, and the bodies of our troops, is not a sufficient defense for our idea of America, of humanity. It takes ideas to defend ideas—and physics can be an arsenal of ideas. Are we too timid to give them full use?

Grateful acknowledgment is made to The Rockefeller Foundation, and also to Betty Lee and Edith O'Connor for assistance.

American Association of Physics Teachers

Summer Meeting

Wesleyan University, Middletown, Connecticut

June 20–22, 1950

Tuesday, June 20

Morning: Registration and visiting laboratories.

Early Afternoon: Symposium on "Piezoelectricity," including, among other things, ten demonstrations in the field of piezoelectricity by Professor K. S. Van Dyke, and a color film on the growth of crystals.

Late Afternoon: Tea at the Honors College.

Evening: Banquet, speakers to be announced later.

Late Evening: Visit to Observatory.

Wednesday, June 21

Morning: Symposium on "The Demonstration Lecture as an Art," including a demonstration lecture by Professor V. E. Eaton and contributions by Professor R. M. Sutton, Professor E. M. Rogers, and others.

Early Afternoon: Contributed papers.

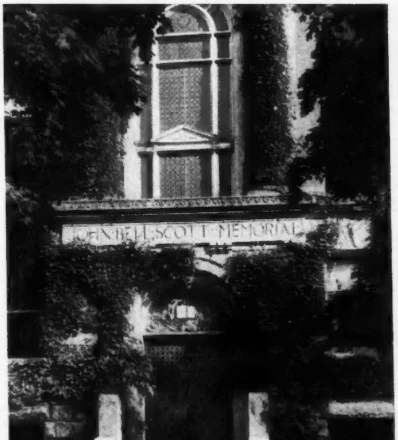
Late Afternoon and Early Evening: Picnic.

Evening: Theater party at a Summer Theater.

Thursday, June 22

Morning: Special features, including a statistical study of the undergraduate training of American scientists by Professor R. Knapp; discussion of a second-year physics course for biology and premedical students by Professor L. L. Barnes; a report on the Taylor Memorial Manual of advanced undergraduate laboratory experiments by Professor T. B. Brown; and other topics.

Special Activity for Women and Children: Boat trip down the Connecticut River, with a picnic lunch.



Scott Laboratory, Wesleyan University, Middletown, Connecticut.

Afternoon: Contributed papers.

Added attractions that may be arranged: Hiking and hill climbing; swimming in Long Island Sound.

Orrin Harold Smith

Recipient of the 1949 Oersted Medal for Notable Contributions to the Teaching of Physics

The American Association of Physics Teachers has made to Professor Orrin Harold Smith, Professor of Physics at DePauw University, the fourteenth of its annual awards for notable contributions to the teaching of physics. Following an address of recommendation by Professor Paul Kirkpatrick, Chairman of the Committee on Awards, the presentation was made by Professor J. W. Buchta, President of the Association, in a ceremony held in McMillan Hall, Columbia University, on February 3, 1950, during the nineteenth annual meeting.

Address of Recommendation by Professor Paul Kirkpatrick, Chairman of the Committee on Awards

THROUGHOUT the past fifteen years the American Association of Physics Teachers' Committee on Awards, with its continually rotating membership, has tried to carry out the charge laid upon it in 1935, a charge which stated that "the duties of this committee shall be the recognition of distinguished teaching and outstanding contributions to the teaching of the science of physics." The committee has always recognized that there are many different ways in which teaching physicists may attain to the measure of distinction appropriate to the Oersted Award. Last year the Oersted Medal was tendered to an outstanding leader of advanced students and author of physics textbooks and treatises. In the year before we were recognizing the creator of the *American Journal of Physics*. In the citations of medalists of previous years we find reference to such achievements as the introduction of laboratory instruction into physics teaching, historical researches, important translations, the founding or administration of institutions favorable to the diffusion of the knowledge of physics. And equal in honor with these medalists who have greatly facilitated teaching stand those men who have greatly taught. We honor one of these today.

ORRIN HAROLD SMITH was born in Iowa in 1884. He took degrees at Knox College and the University of Illinois, and in 1914 he became professor of physics at Cornell College, Mount Vernon, Iowa, where his career as a distinguished and beloved teacher of physics began. In 1925 he became professor of physics at DePauw University, the post which he has since occupied continuously, except for a year which he spent in China at the request of the Rockefeller Foundation.

That his teaching has been great we know upon the testimony of hundreds of his students, scores

of whom have gone on to advanced degrees in physics and thereafter to positions of high responsibility and of professional leadership. The number of his undergraduate students who have elected to make a career of physics is out of all proportion to the sizes of his classes, according to national statistical surveys of these matters. Without doubt, this productivity has been a personal effect; when Smith went to Cornell, that college became a source of good physicists; when he left Cornell the flow from that institution declined abruptly to a mere trickle, and within three years the flow of physicists from DePauw had grown from a trickle to a steady stream. It would be difficult to find a finer example of the influence of a single person upon young men and women in the field of science.

Some of Professor Smith's students have kindly sent me recollections of their student days under Smith's kindly and exacting hand. One comment emphasizes the thoroughness and precision of Smith's instruction, which was relieved by a generous sense of humor and a gift for making up exciting problems. It is clear that Smith preferred a thorough mastery of a few things to the hurried mention of all things.

Smith did not obtain his results without constant effort, as the following student quotation shows: "The thing which has been underneath his great contribution to physics was his wise evaluation of the talents and potentialities of the better students. Each year he would pick out one to five or six students in his elementary class who, in his opinion, have unusual potential talents. To these students he would give especial encouragement. He would talk with them personally about opportunities in the field of physics. He would help them in planning their curricula and would take a personal interest in them through their advanced work. If his original judgment as to their possibilities was verified, he would encourage them in pursuing graduate work and would go to great lengths to assist them in being admitted to a graduate school and securing assistantships or fellowships."

One student writes: "He was known on the campus as a hard teacher, but I have never known one so genuinely beloved by his students."

This view is corroborated by another who says: "His elementary course was generally regarded as one of the tough courses on the campus, but also one of the most popular among the more serious-minded students. Professor Smith's kindly personality, his very deep personal interest in students, his very striking way of explaining and illustrating physical problems, and his untold patience in helping students over difficult points endeared him to all of his students."

Out of a large volume of such testimony grows the clear picture of an able and energetic man, fully absorbed in work completely to his liking; to which his talents and temperament were ideally adapted, and in which he earned the enthusiasm and affection of those he served.

I do not bring in these words of praise either to gratify or to embarrass Professor Smith. I present them for the benefit of the physics teachers here assembled who, year after year at the Oersted ceremony, have been asking themselves, as have I: what did this man have that I lack, and need in my teaching? The elements of success in any art are hard to isolate and measure, but it seems clear in the case before us that this deep personal interest in students, this wholesouled enthusiasm for imparting the thorough training which best serves the student and at the same time makes him serviceable to society was the essential drive which, implemented by appropriate intelligence, knowledge and temperament, obtained for ORRIN HAROLD SMITH the demonstrated success which we recognize here today.

Mr. President, in behalf of the Committee on Awards, I have the honor to present ORRIN HAROLD SMITH with the recommendation that you do tender to him the fourteenth Oersted award of this Association, together with its tangible symbols, the Oersted medal and certificate.

Experience Plus Realization

Orrin H. Smith
DePauw University, Greencastle, Indiana

THE things which I propose to say, in response to Professor Kirkpatrick's very generous presentation, are things about which I hold rather strong convictions but to the support of which I bring no numerical data and not à single slide or graph. The idea of coming before a group like this, to speak in this vein may be presumptuous or even preposterous. But what I wish to say, at least in part, is something not often emphasized in our meetings.

Many of the factors that go into the making of a good job of teaching are neither measured nor counted with confidence. The Great Teacher reminded us once of the importance of the "things that are not seen." One's assurance of their value tends to come at the end of his teaching experience. One embarks on his career with an expectation that they are good and are in the right direction, but by the time he has any considerable basis for them, he is facing retirement from the job.

This paper will be concerned with a number of random suggestions and criticisms on the value of which faith and confidence have come at a slow pace. You will please understand that I am speaking from the standpoint of a small department in a liberal arts college, and I will confine my remarks principally to what is called the major course in general physics, that which usually enrolls majors and minors in all the sciences and mathematics, the pretechnical students, including the premedical, and such others as come from scattered departments of the college who happen to have some particular interest in the course. We have had for years a survey course in physics in our department and I have some enthusiasm for it, but my experience with it is not sufficient for a reliable appraisal.

The Art of Teaching

Perhaps at the outset a belief should be admitted that teaching, even of a science, is more an art than a science. There are certain features that can be measured with some degree of validity, and attempts in these directions should be continued and encouraged. But the actual process of handling a class, of winning its confidence, of spurring the sluggard while encouraging the timid, of tempering overconfidence and hasty judgment, while at the same time encouraging the hesitant to have faith in their own initial steps, is one for which no differential equation (so far as I know) can be written and to which no galvanometer will respond reliably. It is so bound up with that more or less intangible, indefinable thing we call personality—not just one personality with its many variables—but with all the possibilities contingent upon the interplay of at least two of them. Those of you who have made some use of teacher-rating scales have been made to realize, if you had not previously noted it, some of the possibilities of this interaction.

Much of the skill and technique a teacher possesses is acquired as an artist gets his judgment of color, shade, balance, perspective, the use of consonance and dissonance, movement and pose and timing, little of which one can measure but which goes to make up a great painting or dance or symphony. The artist learns by seeing and selecting those things which he himself can use and which come naturally to his own hand. When a teacher is young, much of his technique is imitative until with experience he begins to attain an expression which seems to others and to himself to be his own, so well has it become a part of him and so well has it been shaded and molded to and by himself. This shading and molding must be governed by an innate and cultivated taste. It can be gotten, probably to a large extent, by observation of what looks well and wears well. In some respects, this may be as difficult to determine as it is in music or painting.

As in other arts, tradition (that shackle to the past) may do as much to retard progress as to furnish an inertia that prevents an accumulated wisdom from being blown off its base by every wind of doctrine. The writer has grown to distrust the innovation in any art which discards all anchors to windward about as much as the

slave loyalty that resents any change and points, for justification, to what the system has done in the past. That is to say, he believes in evolution rather than revolution. Our science has developed in that way. Rarely do we come upon a new set of facts or a new theory that entirely and suddenly erases whole pages of published material.

Thus every young teacher should acquaint himself with the current customs and methods and judgments in teaching. Much of this he can and probably does acquire, if he is interested and moderately observant, from his own teachers as he progresses from the high school to the Ph.D. degree. Much can be derived from the simple expedient of recalling, with the Golden Rule in mind, his own experiences as a student. Add to this some attention to the psychology of learning and the philosophy of education, and he will have a reasonably good working capital for a start. He should not forget, however, that physics or any other science is committed to the experimental method. But it should be a wise experimentation that does not impair educational values for those in his classes. Experimenting in teaching is somewhat like experimenting in economics. It should not damage too much of the social fabric. As to how far one dare go here, as in economics, there is a wide diversity of opinion. In both cases the experiments must be carried on with the machine in motion.

Undoubtedly some experimenting should be made, but one would not choose to send a child to a teacher who did very much of it. Educational tragedies have resulted from it. The untrammeled enthusiasm and freedom that are so valuable in the classroom can be cut seriously by a necessarily careful attention to the objectivity required in a controlled experiment. Dr. Leo Nedelsky[1] has sounded a very sane note of warning in this respect in a recent issue of the *Journal*.

As in music and art, the principal thing to be added to a fundamental education in the science is an absorbing interest in scholarship and a desire to share it with those who have all the possibilities of youth—a zeal for and a devotion to scholarship and students. Many of us can recall, as we think back over our own education, how very grateful we are for a few examples of it; and can remember with distinctly contrary feeling those cases where it was conspicuous by its absence.

[1] *Am. J. Physics* **17**, 345 (1949).

In teaching, as in the other arts, one gets hold of some stubborn material over which triumph may be quite meager or even appear to be zero. But as skill and judgment and insight increase with experience, there should be more and more successful events. There is one heartening difference between the two arts of teaching and painting. A good seed sown on a canvas does not often grow, whereas one sown in the mind of even a stubborn student sometimes brings forth a happy and surprising harvest after a very slow germination.

I have come to the conviction, as many of you have, that a triumph over stubborn material (resistance-coupled students as Professor Sutton calls them) requires, among other qualities, a broad knowledge and sympathy as well as an interest in the science. A former professor of mine once said, "There is little in the whole realm of knowledge and observation that cannot be turned to good account in almost any classroom." I would like to rebroadcast that statement, amplified many fold. Like many other teachers of science in his generation, the writer did not major in science but in a classical language. To be sure, he missed much thereby in the knowledge and skills of science, but he gained much that has been put to good use. He would not try to convince a member of the present generation of its value and satisfactions, but there are many things, usually called good, for which he would be unwilling to barter it.

Importance of Basic Principles

It sounds like a truism to say that physics is not the radio nor the auto nor the atomic bomb. But to judge by some of our textbooks, by some of the impressions students seem to get from lectures, and from remarks made by colleagues in other departments of the college, physics is just those things—rather than a knowledge and appreciation of some very beautiful, impressive, useful, and significant laws and principles. This distortion of emphasis is probably due to a feeling that it is necessary in order to hold attention and to 'sell' the physics course. Much

of the time that would be so spent could probably be better spent in an attempt to broaden the scope and comprehension of the fundamental concepts. It seems necessary to pose problem after problem, situation after situation, before any appreciable fraction of a class realizes, even dimly, the depth and power of a principle so simply stated. Newton's second law, for example, said by one commentator to be the greatest single idea ever to spring from the mind of man, requires considerable repetition and application in many connections. If this is done, a reasonable number of students will begin to realize the greatness of it and the value of it. Repeat this for some other laws like the laws of equilibrium, and Bernoulli's law, and many students will change their whole attitude toward the physics course. Failure to do this may be responsible for an all too prevalent feeling among students that these are meaningless assemblages of words which they must learn; and that no more should be expected of them than to be able to repeat certain sounds in response to the right question.

Professor Franklin, a former recipient of this medal, used to be fond of saying, "If you ask a student, 'What is Newton's second law?' he will make sounds like these, 'eff equals em ay'." The report of a medical school dean comes to the same thing when he says of the physics preparation of his enrollees, "they seem to know a lot of things they do not understand." A geologist and mining engineer said to the writer, "I wish I could get some physics students who understood what they thought they knew."

Years of experience have demonstrated that these laws can be taught to a class, given enough time and skill, with a little dramatization, a little good-natured prodding, some good problems, and a vast supply of patience, with the expectation that many students can be brought to a temperature of ignition so that automotivation results, and a new source of energy is launched in the world of intellectual endeavor. It seems to be possible to interest a gratifying proportion of the students in a class in a satisfying understanding of physical laws, even if one never exhibits a radio, an auto, a telephone, or a vacuum tube.

To gain some degree of mastery over the physical principles it is necessary that students be interested in them. Considerable interest can be generated by the very simple plan of making a connected story with a great deal of attention to the interdependence of one part on another, to produce a realization that science is a unit, that the conquest of one part aids greatly in the conquest of others, until the learner has built up a fabric of facts and principles that is a delight to him. This can be done in physics to an extent possible in few subjects in a college curriculum. Perhaps that is one of our peculiar contributions to education. To achieve it, for a reasonable fraction of a class, means a long slow start in any course. But the more the writer seeks to do this, the more he feels it is the right way.

Critical Thinking

One of the things that should be accomplished by a science major in a course in physics is an ability to read scientific and technical material critically and understandingly. To this end we have reduced the lecturing to a minimum. It is flattering to a teacher to see his class avidly grasping, as it were, at the pearls of wisdom which he casts. But most of what he says is in the textbook in one form or another and, as J. J. Thomson once said, "A textbook must be exceptionally bad if it is not more intelligible than the majority of notes made by students. The proper function," he continued, "is not to give the student all the information he needs but to arouse his enthusiasm so that he will gather knowledge himself, perhaps under difficulties."

The class hour is usually spent in a kind of conversation, of informal give and take. Questions are always in order and interruptions are allowed anywhere; books are open and students seek to clarify and amplify the statements made by the textbook and by the teacher. If the discussion lacks vigor, some statement is thrown out that is meant to be challenging, now and then one that is not quite correct although it sounds plausible. In time, more and more students come to read and listen critically. They gradually become more critical of their own statements and advance to the place at which they can state their questions or contentions in very good terms, not calling every quantity a force. The assumption on the part of students that a teacher and a textbook are infallible should be vigorously discouraged. A former

colleague who taught geology has trained some remarkably competent geologists. There is evidence that his insistence on the fallibility of teachers and textbooks was one of the major elements in his success.

An interesting device to keep things going permits the teacher to call for a definition and then misunderstand and misinterpret it as far and as long as he can until some member of the class begins to see all the factors that must go into it and states it in such a form that the teacher must admit that the definition so stated is no longer misinterpretable. This tends to apprise students of their own carelessness in making statements, of their own vague use of scientific terms. It can be done in the spirit of a contest to create considerable participation. There is naturally a delicate line between this attitude and one of antagonism. A recognition of this dividing line will measure somewhat the skill of the teacher.

It is nothing short of remarkable how difficult it is to make students appreciate the requirements of a definition or to understand what can be defined and what cannot. It seems to take an astounding amount of time and repetition to get them to see what a powerful tool for understanding and diagnosis, and solution of problems, a correct definition can be. The same thing is true about the statement of a law, both in good English and in mathematical form, and the interpretation of one of these forms in terms of the other. Most of the laws studied in general physics are convenient excuses for making equations—conservation of energy, the laws of equilibrium, Newton's laws, etc., and these homemade equations are keys that will solve problems that look formidable were they to be attacked by what some of the students are pleased to call the common-sense method. So it must be stressed here that the laws of physics are not substitutes for good common sense but very valuable adjuncts to it. If the equations are to be homemade, the laws from which they are derived must be carefully formulated. To toss a formulation back and forth in the class is to spend time profitably. One law, mulled over until understood and then used until some confidence is generated, is worth any number of equations learned by rote.

For any appreciable fraction of the class to understand this mode of attack takes a long time. It means an exasperatingly slow start; but subsequent progress is the more wholesome and the more rapid. This is more evident in the second- and third-year courses in which the early stress on fundamentals really begins to bear fruit. However, in the first year it means a sacrifice in quantity of material covered. After all, we expect our students to grasp many fundamental ideas of remarkable depth and power in a year's course. When we think of the history of the rise of new ideas and the time it took for their clarification, perhaps we expect far too much. A teacher of chemistry, who during the war taught some physics classes, declares that there are only about a dozen fundamental concepts involved in the beginning chemistry courses while there were 270 numbered equations in the physics textbook he used. Does the author of such a textbook expect students to remember that number of equations? You and I know how simple it would be to pose a problem that would fit none of them. No wonder students "hate the stuff."

So we have come to the plan of covering, more fully, less and less material. The insistence from various and sundry schools and departments that their majors in this course learn something about this and that has fallen on none too sympathetic ears. If students understand some of the basic things, they can to a considerable extent do their own extrapolating. I was interested to hear the personnel director of a large department store say that one of the most valuable assets which he sought in a candidate for employment was an ability to find and to "read up" on what he needed to know. In these days of so much on-the-job training, it would seem the part of wisdom to develop judgment, resourcefulness, method, and a good digestion of a few fundamental principles. Did the writer of the Book of Proverbs say "formulae and many vague ideas are the principal thing, therefore get them?" No, you will remember, "wisdom is the principal thing, therefore get wisdom and with all thy getting get understanding."

Classroom Techniques

Let me say again, clarification through participation is best accomplished in an informal atmosphere of free give-and-take and is valuable enough to retain at some sacrifice. The practices that are prized by so many teachers of giving

"snap" quizzes or frequent ten-minute quizzes, or of grading on class recitations, are sacrificed for the sake of it. The too prevalent practice of grading on recitation performance causes students to cover up their ignorance instead of dragging it into the open. It inhibits participation in the classroom and makes for a learning process that looks to the immediate advantage rather than to the ultimate goal.

Some of these considerations have been reason enough for abandoning the practice of sending students to the blackboard with assigned problems which they copy down and then recite to the class. Much valuable time was wasted at this activity before it was abandoned. There are good procedures to be followed in solving problems just as there are in playing golf. Problems, well chosen, are put in the textbook, presumably to do something for the learner. This something is mostly missed in the explanation given by the average student. He seeks only the answer and is prone to rely in his attack on principles and strategy brought up from his past experience instead of getting practice with and confidence in new and better and more complete principles and methods, the very thing for which the problem was designed. The practice with a pointer before a class has some value which is now lost; but another plan may to some extent offset that loss. The writer has long followed the plan of working the problems at the blackboard with the aid of the class, purposely making some mistakes, stirring up controversies over points of law, accepting suggestions as to procedure even when they are wrong, and running them to the end of a blind alley or to a successful conclusion, as the case may be. Of course, one can see good opportunity for abuseof that practice; but the first quiz can be made an excellent corrective for the abuse.

Much time is spent in class on problems, time to diagnose each problem until the line of attack seems evident, time to work them more than one way, to show the lack of wisdom and good strategy in some of the attacks and to demonstrate that a start in quite a variety of directions can yield the correct result if one can follow his "knows." Evidently it gives students quite a thrill to start out in several different directions and be able to reach the same result. It gives what is so frequently missed—a comprehension of the unity and pattern of the science.

Thus we are rather careful in our choice of the types of problems that are set. Fundamental differences exist among textbooks in this particular. We all know the type of problems that can be found in so many textbooks and in books of problems—the kind that usually requires only that the student search through his book with the assurance that he will find a formula that will just fit it, ready at hand. There is no inducement to be concerned as to how the formula is obtained or what it involves or what its limitations are, because he can be sure that if he memorizes all of them before a quiz, he has at his command a machine, to operate which he need only close the switch and turn the handle. The beauty and the meaning of a law as a basis for many formulas and its comparative universality need never cross his mind. How much will such a student ever appreciate of the spirit and value of science in society, of the scientific method, of creative possibilities? How much comprehension will he have of the basic laws and principles that underlie so much of our useful knowledge? By how much are his potentialities developed?

If preparation for a class in physics, or any other class, consisted in learning by rote many formulas and constants and more or less disconnected facts, or working problems merely by trying the data in this or that formula for which one searched the pages of a textbook or his memory, he would be very cynical about the satisfactions or values of scholarship. Some student remarked about a certain course he was taking, "We go to the class and the professor pours us full and then we go to the quiz and pour it out and it stays out." The pouring process can very quickly become a boring process. I have heard students declare near the end of their first year's work in physics, "This is the only course I have on which I have not gone stale."

The type of examination should be made to fit the classroom technique. Endless testimony can be had from students to the effect that their examinations over the campus are generally such that they must write furiously during the fifty minutes allotted in order to cover, even as it seems to them inadequately, what is called for. They have no time to think, to correct a bad start, to learn to find their own way through the

materials, to see a new significance or a new organization of the material in the process of answering a question that may have been designed to bring out new relationships, new concepts, and new insight. To answer such examination questions satisfactorily, students believe that it is necessary to memorize the material practically verbatim. They dare not risk a departure from the text lest they get lost and have insufficient time to recover a recognizable trail through the material at hand and still have time to complete an impressive paper. Recognition of the need of leisurely examination procedure has caused us to adopt the plan of having the quizzes during and in lieu of a laboratory period of three hours. About forty minutes, at most, are required to write down all that is necessary if the student knows exactly how to start and follow through, which is not expected. In fact, the questions and problems are usually formulated as far as possible to cut across the patterns of the textbook, to be different in some way from any problems that have been discussed in class. They will have unexpected combinations of elements and yet involve underlying principles that have been discussed extensively. A question or problem is considered good if it has several parts so that a correct answer to one part throws light on the attack on the next. The goal is, as it were, to lead the student along a path of discovery. Watching a class in such a quiz, one may see every now and then a flicker on the countenance of someone who has discovered something and is immensely pleased with himself. One indication of the challenge to students by this type of examination is the number of former members of the class who drop into the room to see what they can do with it.

The questions consist of definitions, a little discussion, and problems. There is frequently some attempt to give them a practical or humorous turn in the hope of taking some of the dullness from the afternoon or of reducing the tension. Many students seem to find a challenge in discriminating between relevant and irrelevant data. When some irrelevant data are included, the responsibility for the attack is thrown on to the student. Such a responsibility is something most students are very slow and very reluctant to accept. Some of you will remember a textbook published a few years ago at the front of which was printed these words: "Remember there are no lengths to which a student will not go to avoid the necessity of thinking."

Some of the best students and some of the poorest leave the examination long before the allotted time has expired. There are usually representatives of both types of students left at the end of the three hours. But no student can say that he did not have time to show what he really could do. Many who are inclined to blame the instructor for a disappointing grade have a chance to exhaust their knowledge and ingenuity. They go away quite thoroughly convinced that they have not done a good job on the material covered, and that they have not gone at it in quite the right way.

Self-Reliance and Responsibility

These experiences remind us that one of the things in our modern education that has caused considerable concern is the apparent lack of self-reliance and responsibility among students. Undoubtedly some of it is traceable to methods of teaching used in high school. They are not necessarily methods that have been approved by our departments of education. The condition appears to be induced partly by external pressures of one kind or another. In college it is occasionally fostered by personnel deans who mean well but are, in turn, under external pressures.

Many students seem to be unconcerned over their failure to solve problems without help or suggestions, or without knowing what the answer should be. They depend, to a rather surprising extent, on one another or on fraternity files and other data from the past. We have found a very simple plan in the junior and senior courses that seems to have several merits. We have, for about fifteen years, assigned problems (without answers) to the extent of two or three per week. Students have a week in which to think them over and to come to a final solution. They agree at the beginning of the semester that they will not consult anyone but the instructor about the problem and will confine their search for help to prescribed textbooks. They may come to the instructor for help and will be charged grade points, depending on how much help they accept. If some single part of a problem seems impossible for them to solve, they can get help with it in

order to achieve something other than a zero grade; thus no one works the problem for them and they are careful to ask as little as possible. They are led to decide just what it is they do not understand and whether to risk their tentative solution against the loss of points for help. The correctness of their solutions is thus appraised by the students on their own responsibility. These problems are then handed in and graded, handed back and discussed. The whole scheme has served as an excellent technique to direct students' attention to various parts of the theory and to encourage them to greater effort than mere mental assent to statements made by the textbook or teacher. It may be remarked that for intermediate and advanced courses we aim to choose a textbook that requires considerably more than a cursory reading. Students are held responsible for the material in the assigned portions of the textbook and, as in the beginning course, they need take few or no notes. If there are parts of the text about which no one has a question, it is passed over quickly. The class hour is devoted to explaining questions raised by the students.

It is to be noted that this problem scheme is agreed to with some noticeable hesitation on the part of some of the students; it scares them a little at first. They do not appear to have much confidence in their own thinking. Several points of interest come out of it. (1) Some of the members of the class admit that it is fun. (2) A number show by the errors in their papers that they are not nearly as self-reliant as we or they thought. (3) They discover that it is not the facts which they store away that are the most important things, but whether they understand thoroughly what the theory means and how the facts fit into it with consequent illumination to both. (4) The problems assigned are designed as much as possible to cut across several chapters and even previous or concurrent courses so that, in a certain sense, they constitute a kind of comprehensive examination. A student will frequently say, after handing in his problem, "That made me go back and clarify some things I did not quite understand last year." (5) Men who have gone on to graduate school have testified with enthusiasm that this experience was one of the most valuable of their whole undergraduate curriculum. (6) It makes a teacher realize how much even good students rely on one another in a kind of community effort to discover the answers. Under the above plan the emphasis is placed, as it should be, on careful reasoning and the cogency of the argument. There may be classes or even institutions where this cannot be done, inasmuch as one member of the class, who has a weak spot in his honor, can make it exceedingly difficult for the rest to play fair. Warning is given that, though this procedure is logical and much better than encouraging cramming for quizzes, it requires a high sense of honor. It is a pleasure to note that our young people take considerable pride in their allegiance to this bond. That a member of a group can take an advantage of such a scheme is quite apparent. However, there are usualy little signs which betray the rare individual who cannot be trusted in the agreement. In fifteen years or more, two have been found about whom there was reasonable suspicion. The benefits far outweigh that amount of dereliction. Of course the teacher, himself, must not cast even the "shadow of a turning." It is a source of keen satisfaction to find that so many college students can and will accept responsibility for loyalty and fair play.

The Teacher as Scientist and Citizen

To use a metaphor due, I think, to Harvard's former President Eliot, science "needs men—broad men sharpened to a point." In his day, when the subject matter of science was not so voluminous as it is today, it may have been possible to attain preeminence in both dimensions. Now it is possible only to comparatively few men. Science needs the efficient point. Perhaps for most men it will of necessity be slender but sharp and well tempered, the better to pry into the unknown.

But science needs also men with a broad base even if it entails some sacrifice of the point. There is a limit to the area that most of us can cover. Some breadth of base is necessary to maintain contact with many other aspects of life in order to keep our social integrity. There is occasion for some alarm over the vast gulf that exists between our specialists far out on the slender points of knowledge and the bulk of our citizenry. It is not impossible that there should arise between scientists and laymen as great a

misunderstanding and distrust and even contempt as can exist and has existed between social strata so greatly separated in wealth and privilege, that it appears that men who would step from one stratum to another cannot, and those who might will not. The expression, "cold, hard science" is heard often among nonscience people, even among those who are considered educated men and women. It is a disturbing sound in the wind which calls for the bridging of a distinct and dangerous gap.

We teachers of science know how baseless all these artificial distinctions are, and it is we who can and must play the role of the middle class which has the confidence of and is well understood by those classes at the extremities. We can be the intermediaries who can keep supplies and facilities flowing to the specialist and, in turn, assure the public that there is nothing subversive in the activities of those employed in the most advanced fields of research. We can point out that similar situations in the past have in the long run greatly increased the comfort, convenience, and pleasure of civilized living, and that the chances are good that the present situation will have similar results.

We may go so far as to hope that the spectacular successes in our science may stir this vast public to demand a scientific objectivity and benevolence on the political, social, and economic fronts. We might remind ourselves at this point of that oft-repeated quotation from one of our greatest Americans, "No nation can exist half slave and half free," or to paraphrase, no free nation can continue to exist with a part of its citizenry in brilliant light and part in darkness.

There are giants among us who can play both roles well; but their names are not legion and most of us will have to play one role or the other predominantly. It is by us that most of the work of the world is done, just as the bulk of the taxes are paid not by multimillionaires but by Mr. Average Man.

This broad base will not be attained by a teacher in a day or a year. It will require much time spent in study throughout his life not only to keep his science alive but to get some little knowledge of the fields and problems in other sciences, since physics is basic to so many of them. Much of this can be gotten in a faculty lounge. Fortunately there are valuable journals available now that did not exist twenty-five years ago, *Reviews of Modern Physics*, the journals of the American Association for the Advancement of Science and our own *American Journal of Physics* which has been of the utmost value.

Teaching in a liberal arts college, one cannot ignore or dismiss as unimportant some knowledge and appreciation of the arts, of literature, of religion, and particularly of philosophy. To be lacking in these, a teacher in a liberal arts college has a count or two against him to begin with.

I suspect no one will ever have so broad a base and at the same time so good an understanding of his own field as to make an ideal teacher. That is a shining, distant goal. But I believe he will lose much in value and effectiveness the moment he ceases to struggle toward it.

The undergraduate teacher (who will probably find himself well-loaded with routine duties outside his department) may soon lose contact with many of the far-flung battle fronts of our science. He may have to content himself to "follow afar off." But he should follow. At the risk of having to grope, like Tantalus, for things that are out of his reach, he should attend at least one national meeting of scientists in addition to one or two of our own Association each year. The lift and the inspiration he can bring back to his students are well worth the expense and the effort, to say nothing of what the meetings do to him. This lifting of his eyes toward the guiding stars can do much to correct his bearings and help him to give reliable direction to those who look to him for it. It does much good for a teacher to say to his class that he found that there is a new idea in evidence about this or that, or that he learned at the meeting something new that he had not thought of before; that the trend in such and such a field is in such and such a direction, whereas we once thought the status was so and so. It does much to keep the teacher alive and alert and gives to his students the confidence that they are in contact with a science that is growing and a teacher who can change his point of view.

The teaching profession is a great challenge to a wonderful life: so great that it is probably well that entering on the task one cannot see its magnitude and requirements. This writer would not have missed it for anything.

The New Radioisotope Laboratory of the University of North Carolina*

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FROM time to time during recent years researches have been done at The University of North Carolina (Chapel Hill), in which radioactive isotopes, both natural[1] and reactor-made,[2] were employed. Since only low activities were used, and these not frequently, the work was invariably carried out in the permanent laboratories of The University, care merely being taken that the laboratory buildings did not become badly contaminated. In the winter of 1947–1948 researches were projected in biology, chemistry, and medicine, as well as in physics, involving in all a far greater amount of radioactivity than had ever been contemplated in previous physics researches, and requiring special facilities for the use and control of activity. Accordingly, a small radioisotope laboratory was constructed during 1948–1949 to meet the needs of these projected new researches.

The Advisory Field Services Branch of the Isotopes Division of the U. S. AEC's Oak Ridge Operations, particularly Dr. E. R. Tompkins, and the Training Division of the Oak Ridge Institute of Nuclear Studies generously made available their accumulations of information regarding radioisotope laboratories, so that many features of the new laboratory originated in their suggestions. Certain detailed recommendations were not followed because of cost or convenience, and others were modified for similar reasons; but the basic design and the distribution of equipment accord closely with the recommendations. Since funds were definitely limited, special efforts were made to keep costs down, and herein may be the major contribution of this description.

General Considerations

Since a prime requirement in the present instance was a facility for processing radioactive materials purchased from Oak Ridge or elsewhere, considerable space was allotted to radiochemistry, more perhaps than radiochemical research would demand. The remaining space was deemed adequate for the radioactive phases of investigations in biology, medicine, and physics, because large fractions of investigations in these fields would involve nonradioactive procedures and could be carried out elsewhere. Space was taken in a 25 ft×80 ft war-surplus barracks adjacent to the University's Mathematics and Physics Building and near the Chemistry Building (the Departments of Biology and Medicine were a block or two away) so as to minimize chances of contaminating permanent buildings. Construction was the standard UK-type, with pine flooring and gypsum-paneled walls and ceiling; electric lighting and overhead (steam) fan-radiators had been installed, but not plumbing. Figure 1, showing the floor plan of the finished laboratory, suggests the simple plan of the building as it was before remodeling. Two natural advantages of the building were the doors to the outside, the use of which whenever possible helps to reduce the spread of contamination, and its simple construction, which enables the easy removal of contaminated parts.

Several general design-requirements led to the final plan:

The available area should be divided into three parts, a high level or "hot" area, a medium or low level area, and an inactive area, so as to segregate effectively each working-level of activity. (The inactive area would be used for biometric counting, and for such miscellaneous tasks as study, computation, clothes changing, and minor nonactive experimentation.)

The hot area should contain a fine-aggregate concrete shield adapted to temporary storage of active materials

* The stimulus for this laboratory came from a conference with the Division of Biology and Medicine, U. S. AEC, in Washington, D. C., on January 21, 1948. Radioisotope researches have already been carried out in it, under contracts of the University with the ONR (No. N8-onr-60500) and with the U. S. AEC (No. AT-(40-1)-270), as well as under the University's local programs. The authors are indebted to Drs. Frank P. Graham, R. B. House, and P. E. Shearin, who made the venture possible.

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[1] T. N. Gautier, "The scattering of fast electrons in light gases," *Physical Rev.* **63**, 456 (1943).

[2] J. S. Barlow and F. T. Rogers, Jr., "On the positive particles occurring from P^{32} in the cloud chamber," *Physical Rev.* **74**, 700 (1948).

and to initial dilutions of 25-millicurie lots of newly purchased activities. A small amount of bench space should be provided adjacent to the shield, for general use of higher levels of activity.

Hoods, preferably of stainless steel, should be equipped with blowers capable of moving air across hood faces at 150 ft per min. (Presumably higher face velocities would reduce the chance of escape of activity through transpired air, but recent tests at the Oak Ridge Institute have shown that excessive velocities may cause eddies.)

The counting room should be air-conditioned, because some counters and circuits do not operate satisfactorily in the hot, humid climate of central Carolina.

All bench and table tops which might become contaminated should be protected by stainless steel trays having rolled edges two inches high. (Stainless steel is well suited to this application because dilute HCl sufficiently dissolves it to remove contamination.)

The floor should be finished with asphalt tile laid on a heavy grade of felt, the felt being laid on the wood floor with water-soluble paste. The finished flooring should be heavily waxed before any activity would be brought into the building.

Two major economies were effected in applying these general specifications. First, all engineering, construction, and installation of benches, cabinets, hoods, electric and plumbing services, including painting and flooring but not air-conditioning, were done by the University's Buildings Department. Second, substitute materials and designs were used wherever they would facilitate local fabrication at less expense. Hoods, for example, were redesigned for construction of aluminum-lacquered masonite costing about one-fourth as much as the desired stainless steel; in this instance it now appears that the substitution was a decided advantage, for instead of attempting to decontaminate an area of welded stainless steel hood, one has only to remove a contaminated panel, dispose of it, and replace it with a new one. All such modifications were made so as not to interfere with those three specialized functions of a radioisotope laboratory, *viz.*, to provide protection against radiation, to allow complete and continuous control of active materials, and to be prepared for inevitable lapses of control. Clearly the plan shown in Fig. 1 derives from these general requirements.

Details of the Laboratory Design

Although the disposition of furniture and equipment shown by Fig. 1 is in part a matter of preference, certain features deserve comment.

Most striking is the heavy concrete barrier, shown in Fig. 2, just inside the west entrance. Its two-foot thickness provides about two tenth-value layers of absorption for ordinary gamma-activity;[3] together with appropriate shields of lead bricks about active materials on bench-surfaces or in recesses, it protects workers in the immediate vicinity from all but a fraction of "tolerance" dosage[4] of gamma-radiation from 25-millicurie amounts of the ordinary gamma-active materials. As precautions against splashes and spills, each recess is floored with a stainless steel pan, the walls being draped with Koroseal sheeting. The upper recess on the north side is used primarily for making dilutions, and steel rods embedded in the concrete serve as highly convenient anchor points for apparatus and mirrors. The other upper recess serves as a temporary storage bin for primary dilutions and volatile materials, and is hooded over; storage is in individual cylinders of lead with inch-thick walls. Storage is under lock, withdrawals being made only under the supervision of a senior worker who makes appropriate entries in a system of accounts so as to show a continuous record of receipt and disposal of all activities. Two recesses at floor level may also serve as emergency storage areas.

The eastward extension of the concrete shield is only 18 inches thick, but in general, distance

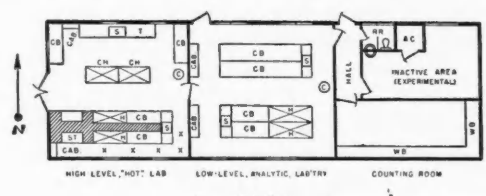

FIG. 1. Floor plan of the Chapel Hill radioisotope laboratory. The concrete barrier, the top of which is indicated in crosshatching, is sketched in detail in Fig. 2. Various other items are: *CB*—chemical bench; *CAB*—cabinet; *S*—sink; *T*—table; *CH*—"California" hood; *ST*—temporary active storage; *H*—chemical hood; *C*—centrifuge; *RR*—rest room; *AC*—air-conditioner; *WB*—work bench. The area *XX* is used for unpacking new shipments of active isotopes. Utilities services are not shown.

[3] G. W. Morgan, "Some practical considerations in radiation shielding," Circular B-4 of the Isotopes Division, Oak Ridge Operations, U. S. AEC (1949).

[4] It should be pointed out here that the concept of the tolerance dosage seems to be dying out, being replaced by that of a "permissible" dosage.

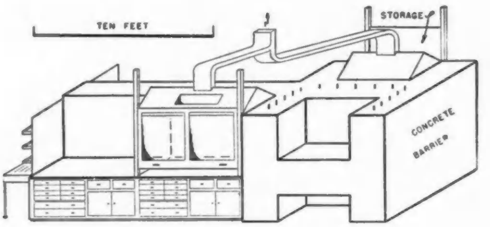

FIG. 2. The concrete barrier as seen in isometry from the northwest; see text for details. The sketch is to scale except for ducts and hood details.

provides the equivalent of shielding here; this extension is draped with Koroseal, again to keep splashes and spills away from the concrete. A common exhaust serves both the storage and the chemical hood, air-flow being controlled by dampers in the ducts. The ducts, their centrifugal fans and associated explosion-proof motors, are located so as to be completely accessible for inspection, dismantling, and replacement, for such accessibility is necessary in controlling contamination. Exhaust stacks extend ten feet above the roof, and are equipped with baffles to insure maximum mixing of the exhaust gases; taller stacks are probably not necessary for the present volume of exhaust. The interior of the chemical hood is plain and smooth, except for a two-inch drain pipe in a rear corner. All service taps and electric outlets are *outside* the hood, near holes drilled through the walls; these holes are kept corked except when service lines are brought through them in rubber tubes. With this arrangement expensive remote-control valves are not needed. As in all hoods in this laboratory, stainless steel trays are fixed to the floors to prevent their being moved by air drafts when the front panels are drawn shut, and illumination is from above by fluorescent lamps placed outside.

Transversely across the end of the concrete barrier is a deep metal sink with double drainboards; foot-operated controls for both hot and cold water are intended to minimize transferral of contamination and the breakage of glassware held in rubber-gloved hands. In place of standard peg-type drying boards over the sink, there is a rack of shallow trays lined with stainless steel wire-mesh, which eliminates almost all transferral of contamination by dripping.

There are, in the high level laboratory, two California-type hoods for radiocarbon syntheses under vacuum, the original designs having been modified to allow only under-hood, vacuum-pump mounting and to eliminate all ledges and surfaces on which dust might accumulate. Essentially, each of these hoods is just a frame 6 ft tall, 6 ft long, and $1\frac{1}{2}$ ft deep, enclosed on all sides by doors or sliding panels (of glass or transparent plastic), such that apparatus clamped on the central build-up rack can be reached from either side.

The low level laboratory differs from conventional chemical laboratories only in that stainless steel trays are used throughout, that it contains only high velocity hoods (two), and that it is equipped with nondrip drying racks. Although only low levels of activity are used in it, they are so often used in the hoods that a $\frac{1}{4}$-inch thick sheet of Kirksite (specific gravity 6.7) is inserted between the rear panels of the hoods for shielding. Traffic between this room and the others is encouraged to go via the outdoors as much as possible, but a glass-paneled swinging door between it and the hot laboratory allows easy and safe passage when necessary.

The original east room has been divided into smaller rooms for greater convenience. Of particular interest is the counting room, which is completely insulated and air-conditioned, and completely shielded against electrical disturbances from the nearby Physics Laboratories by copper screening. A three-ton air-conditioning unit has proved satisfactory, for although it is not equipped with a humidistat, the relative humidity in the counting room stays between 50 and 60 percent when the temperature is held between 70° and 74°F. Since the room is effectively sealed, some fresh air is drawn in continually.

Against two walls of the counting room is a plain, linoleum-covered bench of massive construction suited to supporting lead shields and barriers as well as ordinary apparatus. There is an electric bus bar along the back of this bench for grounding electrical equipment, and plenty of space beneath the bench for batteries, voltage regulators, and electronic gear not requiring manipulation while in use. Pull-out boards are provided at frequent intervals and are extremely convenient.

The remaining inactive room presently con-

tains desks, chairs, bookcases, a blackboard, and the like, as well as a wash-basin and clothes hooks. Now used for work auxiliary to experimentation, it is thought of as a space for expansion when future researches demand it.

Discussion of Costs and Utility

The major consideration in designing this new radioisotope laboratory was to develop a facility which would safely serve the minimum requirements of diverse researches, since the excessive cost ruled out any thought of a laboratory self-sufficient in servicing such researches. That so much space is devoted to chemistry is inevitable and good. That no more is specifically designated for other fields of work, aside from the east rooms, is perhaps more advantageous than disadvantageous since the spread of contamination is somewhat inhibited by virtue of the fact that preparatory tasks are done elsewhere. The laboratory's general utility may be judged in the light of these remarks by successful studies using ${}_{6}C^{14}$, ${}_{16}S^{35}$, ${}_{30}Zn^{65}$, and ${}_{53}I^{131}$ in biology, chemistry, and physics since March, 1949, and by the fact that cross-contamination of radioisotopes has not occurred.

At least eight persons have been able to use the laboratory without interfering with each other, and several more could probably work safely and efficiently at the same time. Standard health precautions are taken, involving periodic blood counts, periodic area-monitoring, and the wearing of pocket-type, gamma-radiation meters. Because the working group has been small and closely knit, and because most workers have been responsible, experienced senior investigators, it has not been necessary to enforce stringent rules and regulations of procedure. Nevertheless, a set of rules has been adopted and followed against the time when it will be absolutely necessary; these rules, though not original, have been cast in forms especially suited to this laboratory, and are given in the Appendix as a matter of related interest.

Experience has suggested a few defects, some of which have been remedied:

Floors of the California hoods should be another eight inches higher so that large vacuum pumps could be placed beneath them; they are now 16 inches above the laboratory floor. All service taps should be placed outside them.

A drinking fountain with foot-pedal control should be placed in the northeast room.

A convection-radiation heating system would be preferable, since the present system causes air-currents which may stir up dust, but it could not economically warm the huge volumes of air exhausted by hoods. The solution to this problem is not clear.

The air-conditioner closet should be lined with acoustically absorbing material, and its floor should be shored-up to reduce noise and vibration.

Hoods should be modified to incorporate eddy-proof air-flow at their faces, since the Oak Ridge Institute has demonstrated this to be feasible; a suitable molding on the edges of each working face is sufficient to produce stream-line flow at face velocities lower than 150 ft/min.

As a final comment, the capital investment in this laboratory is quite low. It is not possible accurately to estimate the value of land associated with it, but the building was worth about \$10 per sq ft when new. The cost of remodeling and outfitting to the extent here described was \$6.87 per sq ft, as follows:

Air-conditioning for counting room	\$0.60 per sq ft
Hoods and their chemical benches, including blowers but not ducts	1.25
Ducts	0.95
Other chemical benches	0.60
Electrical shield for counting room	0.07
Other electric installation	0.25
Stainless steel units	0.75
Plumbing	0.90
Concrete shield for hot room	0.20
Bench for counting room	0.25
Cabinets	0.20
Other items and services	0.85
Total	\$6.87

(It will be noticed that itemized costs are referred to the total area, 2000 sq ft, of the laboratory.) And although it was not necessary to retain architectural services, the present authors contributed their time and efforts to a total amount of approximately \$0.50 per sq ft. That it was possible to obtain this isotope-research facility for the small sum of \$17.37, exclusive of land, per sq ft, is significant. The enabling reasons were, essentially, that the facility is a minimal one, that it is suited to work at most with levels of activity one or two orders of magnitude below

the curie, and that the whole venture was handled on a nonprofit basis. It is hoped that the present experience may serve as a guide in the development of additional, generally similar laboratories elsewhere, particularly under analogous limitations of money.

Appendix

Rules For The Radioisotope Laboratory
Chapel Hill, 1949

1. No person is to enter the laboratory, especially the radiochemical areas, unless he has reason to. There must be no casual visitors.

2. Laboratory coats worn in the hot area shall be kept there, and those worn in the radiochemical areas must not be worn elsewhere in the building.

3. All *isotope work* is to be carried out while wearing *laboratory coats and rubber gloves*. For certain operations the senior worker only may permit gloves to be dispensed with.

4. Pocket-type ionization meters, properly charged, must be worn throughout all manipulations of isotopes; the daily dosage must be read and recorded. Blood counts will be secured monthly.

5. Each worker is responsible for keeping his working space clean and uncontaminated. All spills, regardless of size, must be reported to the senior worker.

6. No radiochemical operation is to be carried out unless another worker is in the laboratory, available to render assistance in case of mishap. Radiochemical portions of work must be carried out in the daytime and should not be rushed or hurried.

7. Use diaper paper over stainless steel trays for all radiochemical operations. Work in the hood if there is the slightest chance of volatilization.

8. Each worker is individually to clean up and/or dispose of his contaminated material. Use only labeled cans and jars for the contaminated waste.

9. A general clean-up is necessary once a week. Avoid raising dust, by wiping all surfaces with oiled or moistened cloths. The laboratory will be monitored once a week.

10. All unused activities are to be kept locked in laboratory storage. Removal of stock isotopes from the safe is to be done only with the approval of the senior worker. A complete record must be kept of all activities received and taken out.

11. The health physicist is to be consulted in planning experiments and procedures, and whenever unfamiliar situations arise. He has the power to veto any procedure which is obviously not safe and which leads to excessive exposure to radiation.

12. There will be POSITIVELY NO SMOKING, EATING, DRINKING, OR APPLYING OF COSMETICS in the radiochemical areas of the laboratory at any time.

13. Noncompliance with any of these rules will result in the withdrawal of the use of the laboratory from the person involved.

There is a very renowned argument much prized and much quoted by theologians, in which the universe is compared to a watch. Let us deal practically with this comparison. Supposing a watchmaker, having completed his instrument, to be so satisfied with his work as to call it very good, what would you understand him to mean? You would not suppose that he referred to the dial-plate and the chasing of the case behind, so much as to the wheels and pinions, the springs and the jewelled pivots of the works within—to those qualities and powers, in short, which enable the watch to perform its work as a keeper of time . . . I do not wish to say one severe word here to-day, but I fear that many of those who are very loud in their praise of the works of the Lord know them only in this outside and superficial way. It is the inner works of the universe which science reverently uncovers; it is the study of these that she recommends as a discipline worthy of all acceptation.—John Tyndall, Fragments of Science, Vol. II, p. 94.

Optical Evaluation of Molecular Structure Factors*

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INTRODUCTION

IN a lecture entitled "Lightning Calculations with Light," Bragg[1] described a series of optical-diffraction experiments in which the intensities in the diffraction patterns gave the values of several functions which occur in calculations used in the determination of crystal structure. This method of evaluating the intensities of crystal reflections has been used by Bunn[2] in the determination of the crystal structure of penicillin and has been refined by Stokes[3] and de Vos.[4] In the present paper there is a discussion of the optical method for determining molecular structure factors. The relation of the molecular structure factor to certain electron- and optical diffraction patterns is described.

The molecular structure factor may be defined as

$$T(\xi_1\xi_2\xi_3)=\Sigma_r f_r \exp 2\pi i(x_r\xi_1+y_r\xi_2+z_r\xi_3). \quad (1)$$

In this expression, f_r is the x-ray scattering factor of the rth atom in a molecule. The position of this atom from an arbitrarily chosen origin is given by the vector $x\mathbf{a}+y\mathbf{b}+z\mathbf{c}$. The coordinates ξ_1, ξ_2, and ξ_3 determine a vector $\xi_1\mathbf{a}^*+\xi_2\mathbf{b}^*+\xi_3\mathbf{c}^*$, where the vectors $\mathbf{a}^*$, $\mathbf{b}^*$, $\mathbf{c}^*$ are chosen reciprocal to the vectors, $\mathbf{a}$, $\mathbf{b}$, $\mathbf{c}$.[5]

From a single two-dimensional diffraction pattern, this function may be evaluated only in two dimensions. The connection between the molecular structure factor and an optical diffraction pattern may not be obvious and will be shown here. First, however, it is desirable to point out its use in crystal structure work.

If a specimen, which diffracts x-rays or electrons, contains molecules which scatter independently of one another, a diffuse diffraction pattern results, and its intensity varies as the square of the molecular structure factor. In such a case, the intensities scattered from neighboring molecules are assumed to be simply additive. Irregularity in the spacing of neighboring molecules may be the cause of the random phases in the radiation scattered from different molecules. One cause of an irregularity in spacing may be thermal vibrations of relatively rigid molecular units whose intramolecular binding forces are considerably stronger than their intermolecular forces. Diffuse electron-diffraction patterns which have been interpreted in this way have been reported by Fisher[6] for stretched natural rubber, and by Charlesby, Finch, and Wilman[7] for a single crystal of anthracene.

The exact nature of the role of the molecular structure factor can be seen from the following analysis of the intensity in an electron diffraction pattern: When a beam of wavelength λ is scattered from a molecule through an angle ϕ the intensity is

$$I(\mathbf{S}-\mathbf{S}_0)=u(\phi)\left\{\Sigma_r(Z_r-f_r)\exp\left[\frac{2\pi i}{\lambda}(\mathbf{S}-\mathbf{S}_0)\cdot(x_r\mathbf{a}+y_r\mathbf{b}+z_r\mathbf{c})\right]\right\}^2, \quad (2)$$

where $u(\phi)$ is a function which decreases regularly with increasing scattering angle, and the expression in curved brackets represents the vector sum of the amplitudes scattered from the atoms of the molecule. Specifically, the rth atom has a nuclear charge Z_r; f_r, the x-ray scattering factor, is the electronic screening of its nuclear charge; $x_r\mathbf{a}+y_r\mathbf{b}+z_r\mathbf{c}$ is its position relative to an arbitrary origin of an arbitrary coordinate system; and $\mathbf{S}$ and $\mathbf{S}_0$ are unit vectors in the directions of the diffracted and incident electron beams, respectively.

Since the electronic screening of an atom is nearly proportional to the atomic number, Z_r can be replaced by its approximate value, $f_r g(\phi)$,

* Communication No. 1306 from the Kodak Research Laboratories.
[1] W. L. Bragg, *Nature* **154**, 69 (1944).
[2] C. W. Bunn (unpublished results).
[3] A. R. Stokes, *Proc. Phys. Soc. London* **58**, 306 (1946).
[4] P. J. G. de Vos, *Acta Crystallographica* **1**, 118 (1948).
[5] For definition and properties of reciprocal vectors, see A. H. Compton and S. K. Allison, *X-rays in theory and experiment* (D. Van Nostrand Co., Inc., New York, 1935), p. 808 ff.
[6] D. Fisher, *Proc. Phys. Soc.* **60**, 99 (1948).
[7] Charlesby, Finch, and Wilman, *Proc. Phys. Soc.* **51**, 479 (1939).

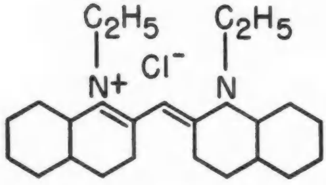

FIG. 1. 1,1′-Diethyl-2,2′-cyanine chloride, photographic sensitizing dye.

and Eq. (2) is simplified to

$$I(\mathbf{S}-\mathbf{S}_0)=w(\phi)\left\{\Sigma_r f_r \exp\left[\frac{2\pi i}{\lambda}(\mathbf{S}-\mathbf{S}_0)\cdot(x_r\mathbf{a}+y_r\mathbf{b}+z_r\mathbf{c})\right]\right\}^2. \quad (3)$$

If $(\mathbf{S}-\mathbf{S}_0)/\lambda$ is defined as $\xi_1\mathbf{a}^*+\xi_2\mathbf{b}^*+\xi_3\mathbf{c}^*$, then, using the property of reciprocal vectors that $\mathbf{a}\cdot\mathbf{a}^*=1$, $\mathbf{b}\cdot\mathbf{b}^*=1$, and $\mathbf{c}\cdot\mathbf{c}^*=1$, the expression in curved brackets in Eq. (3) can be expressed in the same form as Eq. (1). The intensity in the electron-diffraction pattern is then proportional to the square of the molecular structure factor.

An important property of Eq. (3), when the wavelength is chosen so that the angle between $\mathbf{S}$ and $\mathbf{S}_0$ is small and $\mathbf{c}$ is chosen nearly parallel to them, is that the value of z_r is unimportant, since under these conditions $(\mathbf{S}-\mathbf{S}_0)\cdot\mathbf{c}\approx 0$. This means that a projection of the molecule on a plane in the direction of the incident electron beam (or light beam, as will be seen) will give the same diffraction pattern as the three-dimensional molecule at small angles of diffraction.

Examination of Eq. (3) indicates that it is suitable for expressing the intensity in a diffraction pattern obtained using visible wavelengths, provided the point at position r scatters with an amplitude proportional to f_r. Of course, the coefficient, $w(\phi)$, will have a different form at visible wavelengths from that which applies to electron scattering. Since a plane projection of the molecule can be used equally as well as the molecule itself at small diffraction angles, a molecular model for the optical experiments may consist of a photographic plate having transparent holes in an opaque background. The radius of a hole must be proportional to f_r or to the atomic number of the corresponding atom in the molecule, and the positions of the holes must correspond with projections on a plane of the atoms. If the ratio between optical wavelength and electron wavelength is equal to that between the size of the molecular model and the molecular size, the positions of diffraction maxima in the two patterns will be identical and the patterns will differ only in the rate of decrease of intensities with diffraction angle.

The impetus to use the optical-diffraction scheme for determining the square of the molecular structure factor came from some electron-diffraction patterns of an adsorbed layer of a spectral sensitizing dye on a large single crystal of silver bromide. Some diffuse patterns, suggestive of independent scattering from the molecules, were obtained from the dye, 1,1′-diethyl-2,2′-cyanine chloride, the structure of which, on the basis of known bond lengths and angles in such molecules, is indicated in Fig. 1. If the structure of a molecule is assumed to be known, the only problem is to determine the orientation of the molecules in the adsorbed layer.

Experimental Procedure

The electron diffraction patterns were obtained by projecting a beam of 40-kv electrons at a glancing angle of incidence to the surface of the silver bromide crystal on which the dye had been adsorbed. The wavelength of such electrons is roughly 0.06A, and the diffraction pattern is recorded within just a few degrees of the incident direction. The amount of diffraction information obtained from the adsorbed dye layer was very meager, but, from the optical diffraction data and other information concerning the dye layer, a possible solution as to the nature of the orientation of the dye molecules has been obtained.

The optical diffraction patterns were obtained using the simple geometrical arrangement shown in Fig. 2. In this diagram, S represents a light source, which was a 2-watt Western Union Concentrated-Arc Lamp; M is the projected molecu-

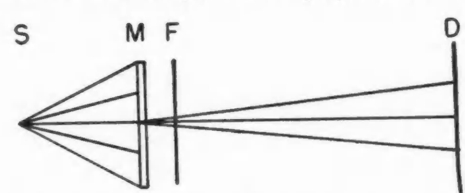

FIG. 2. Arrangement of optical-diffraction experiment.

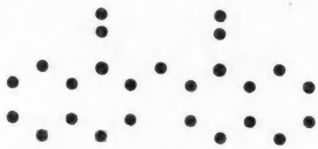

FIG. 3. Model of dye ion.

lar model consisting of transparent holes on an opaque background; F is a Wratten filter; and D is a photographic film which records the diffraction pattern. The separation between S and M was about 3 cm, and that between M and D was about 15 cm. The arrangement of the radiation source, scatterer, and recorder is the same as was used in the electron diffraction experiments and is simpler than the scheme pictured by Bragg,[2] in that no lenses are used in the present arrangement. Collimation of the light beam occurs automatically in this scheme, because of the small diameters of the light source and molecular model.

Sufficiently monochromatic light was obtained by using a Kodak Wratten Filter No. 36, giving a peak transmission at 4200A in the blue, and a blue-sensitive film which does not record the red light which is passed by the filter. Kodak Blue-Brand X-Ray Film was used for this purpose, since it was at hand at the moment. Instead of recording the pattern photographically, it could be observed visually by looking toward the light source through the molecular model.

Preparation of the molecular model deserves special comment, since it is the only part of the experiment requiring particular care. The final model was rather small, and very fine grain plates (Kodak 548-GH Spectroscopic Plates) had to be used to obtain sufficient resolution.

The original model before photographic reduction consisted of black disks on a white background. These disks had diameters proportional to the atomic numbers of the atoms they represented and were placed in positions corresponding to the structure assumed for the molecule projected on a plane. A reduced photograph of the model of the dye molecule being considered is shown in Fig. 3. Hydrogen atoms are not included in the model because of their relatively small scattering factor, and the chloride ion is not included for lack of knowledge of its position.

The next step in preparing the model was a simple copying reduction of the black-disk model. At this stage, the size of the molecule was such that the carbon-to-carbon distance in the benzene ring was 1.01 mm. From this point on, a microscope, from which the eyepiece had been removed, was used for making two further reductions. By putting the molecular model near the position usually occupied by the eyepiece, a reduction of $(1/8.8)\times$ was obtained from an objective, the usual magnification of which is $10\times$. In another step, using a $6\times$ objective, a further reduction of $(1/5.3)\times$ was obtained. In this final model, the carbon-to-carbon distance was about 0.022 mm, and the diameters of the carbon atoms were roughly one-fifth of this.

Because of the limited depth of focus of the lenses used, the fine vertical adjustment on the microscope was of great value in ensuring a proper focus on the photographic plate. To obtain the best focus, several exposures were made at various settings of the fine adjustment, and the best models for use were chosen under the microscope.

After the first copying reduction, an alternative scheme for making the final model was used. In this method, the apochromatic lens described by Perrin and Hoadley[8] was used to give a reduction of $(1/78)\times$ in one step. The record on 548-GH emulsion on film was then contact-printed, a contact oil being used to give the final model. Microscope objectives would be used for making the reduction in most laboratories, since they are the best lenses available.

In making the photographic reductions, some filling-in of the holes occurs in the last step when sufficient exposure is given for producing a dark background. For this reason, some errors will be introduced in the form of inexact relative atomic scattering powers.

It may be seen readily that the computations involved in calculating the molecular structure factor for a large molecule become quite long, but the time required in the experimental steps involved in producing the corresponding optical-diffraction pattern remains essentially unchanged. Hence, the experimental method may prove quite helpful with complicated molecules.

[8] F. H. Perrin and H. O. Hoadley, *J. Optical Soc. Am.* **38**, 104 (1948).

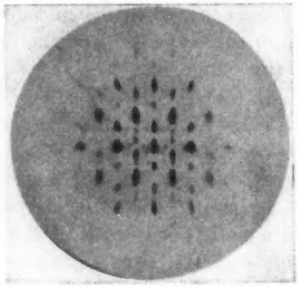

FIG. 4. Diffraction pattern of dye ion.

Results

The diffraction pattern from the dye model, reduced with the apochromatic lens, is shown in Fig. 4. The greater sharpness of spots in the horizontal direction is as expected because of the larger number of diffracting centers along this direction. The general hexagonal appearance of the pattern is striking, and arises from the four six-membered rings in the dye.

An interesting comparison may be made with the pattern of a benzene model, reduced by the microscope objectives, and shown in Fig. 5. The intensity distribution in this pattern, except for the rapid decrease with scattering angle, corresponds well with the contour map of this function shown by Booth.[9] The gradual change from the benzene pattern to that of the dye, on adding atoms to the structure, is interesting. A large step in this direction is shown in Fig. 6, which is the pattern of two fused six-membered rings of the dye molecule.

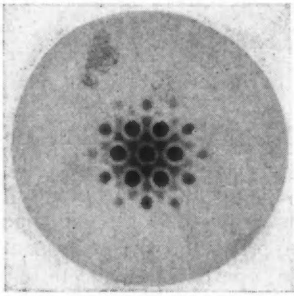

FIG. 5. Diffraction pattern of benzene.

[9] A. D. Booth, *Fourier technique in x-ray organic structure analysis* (Cambridge University Press, 1948), p. 33.

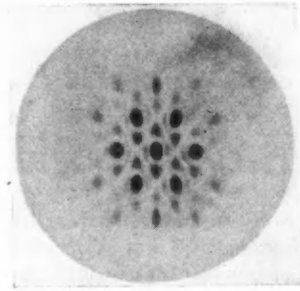

FIG. 6. Diffraction pattern of two fused six-membered rings.

The change in diffraction pattern of the dye molecule, when its plane is rotated through an angle α about some axis in the plane, is of interest. The molecular model for such a case may be constructed by projecting the molecule on a plane rotated through an angle α from the plane of the molecule about the appropriate axis. However, nearly the same diffraction pattern will be obtained in this case, where the molecule is assumed to be flat except for one carbon atom in each of the two ethyl groups, merely by rotating the reduced model of Fig. 3 through an angle α about the axis in its plane. Such a diffraction pattern was obtained and agreed with the expectation, for small angles of diffraction that each part of the pattern for a plane molecule should move normal to the rotation axis to a greater distance by a factor secant α from the projection of this axis in the plane of the photograph.

The detail in the pattern of Fig. 4 is considerably greater than that observed in the electron diffraction patterns of the adsorbed dye layer. Indeed, the electron diffraction pattern contains only one definite reflection, this rather diffuse and occurring in a direction from the center of the pattern parallel to the normal to the supporting surface of silver bromide. With only this pattern and the molecular structure factor to compare with it, the possibility of deciding on the meaning of the electron diffraction pattern would be rather remote. However, we can make use of some of the results of adsorption experiments reported by Sheppard.[10] These results were obtained by comparing the value for the average area covered by a single dye molecule with

estimates by Huggins[10] of areas required for such molecules in various configurations, and it was concluded that the adsorption is edge-on, probably with the molecular planes tilted somewhat from the normal to the substrate. The position of the observed diffraction spot would agree with edge-on adsorption and a tilt of $53 \pm 2°$ from normal. In this case, the reflection observed in the electron diffraction pattern corresponds with the reflection in Fig. 4, which is directly above (or below) the central spot. The reason why no more spots are observed in the electron diffraction pattern is probably that the orientation of the molecules about the normal to the substrate is random.

Summary

The similarity between the electron diffraction pattern of molecules scattering independently and the optical diffraction pattern of suitably prepared two-dimensional models is demonstrated. Both patterns have intensity distributions which are proportional to the square of the function called the molecular structure factor. This permits the interpretation of the electron diffraction pattern to be checked by performing an appropriate optical diffraction experiment as an alternative to making the tedious computation of the molecular structure factor. Some details are given of the experimental procedures which were used in forming the optical diffraction patterns from the model of a cyanine dye molecule. There is given a possible interpretation, involving many assumptions, of the electron diffraction pattern of the dye adsorbed on a silver bromide crystal.

[10] S. E. Sheppard, *Atti del X Congr. Intern. di Chim., Rome* 1, 234 (1938).

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The author wishes to thank Mr. J. H. Altman, of these Laboratories, for his advice and assistance in preparing the molecular models with which the optical diffraction patterns were made.

Joseph Razek, 1899–1950

DR. JOSEPH RAZEK died at Bryn Mawr, Pennsylvania, on February 21, 1950, after a long illness. He is survived by his wife, Josephine Razek, a daughter Eileen, a son, Joseph, Jr., and his mother, Mrs. Frances Razek.

A native of Czechoslovakia, DR. RAZEK came to St. Louis, Missouri, with his parents when he was four years of age. He was graduated with the degree of B.S. in mechanical engineering from Washington University in 1921, and he received his Ph.D. in physics from the University of Pennsylvania in 1930.

He taught mechanical engineering at Washington University and at Pennsylvania State College. He was a member of the department of physics at the University of Pennsylvania from 1926 to 1940. During the past ten years, DR. RAZEK owned and directed a research laboratory which specialized in developing new electronic equipment for use in diverse applications in such various general and special fields as medicine, acoustics, food packaging, concrete mixing, flow metering, and color analysis. He was technical consultant for several large companies, and held 30 patents for his own inventions. During the recent war his laboratory received a Navy E for outstanding defense work. In 1947, he and Dr. P. J. Mulder were jointly awarded a Certificate of Merit by the Franklin Institute for their development of a color analyzer.

He was a registered engineer in the State of Pennsylvania, a member of Sigma Xi fraternity, the Franklin Institute, the Rittenhouse Astronomical Society, the Physics Club of Philadelphia, the Optical Society of America, the American Association of Physics Teachers, and the American Physical Society.

DR. RAZEK will be remembered by his associates and former students as an enthusiastic and inspiring teacher, and as a tireless and ingenious research worker.

M. R. WEHR

Abstracting and Indexing Services of Physics Interest *

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American Institute of Physics, New York 22, New York

PREPARATION of the following list of abstracting and indexing service constituted one phase of the Study of Physics Abstracting recently conducted by the American Institute of Physics.[1] In compiling the data presented here, the authors (a) have included all the services they could find—domestic and foreign—which appeared to deal with material any appreciable fraction of which might be of physics interest and (b) have tried to give, for these services, the kind of information that would make the list most useful to physicists and technical librarians. A subject, title, and agency index follows the list.

Journals and services are arranged in alphabetical sequence. If a word in the name of a journal or agency has subject significance, the title that appears at the head of the entry is inverted to place that word first. Although some of these inversions do violence to conventional methods of alphabetizing titles, they are believed justified here by the added usefulness they give the list. The exact title of each agency, journal, and service appears in correct form both in the body of the entry and in the index.

For the great majority of entries, the information was obtained from a questionnaire filled out by the editor of the service or agency; whenever possible the editor's phraseology has been preserved in the description which appears first in the entry. In most cases the write-up, in essentially final form, was also submitted to the editor for prepublication approval. Services from which completed questionnaires were not obtained are starred (*) in the list; entries for these were prepared from copies of the journal or index itself and were not checked by a representative of the service. In preparing British entries the authors frequently made supplementary use of the list of British and Dominion abstracting services published in June, 1949 by the Royal Society and wish herewith to make grateful acknowledgment of this valuable assistance.

* Copies of this list may be obtained from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., after about July 1, 1950; the OTS serial number of the list will be PB-99951 and the price 75 cents.

[1] The Study was supported under a contract with the ONR, U. S. Navy; results of other phases of the project will be published in later issues of this journal.

1. Acoustics, Contemporary Papers on

Description: References (no abstracts) are given to articles having some relation to sound including ultrasonics, underwater sound, theory of vibrations, hearing, speech, musical instruments and others. Service attempts to be reasonably comprehensive. Books and some pamphlets also are covered.

Magnitude (approx): 1200 references per year; 35 technical periodicals, in addition to a number of abstract journals from which references are obtained.

Indexes: For years 1937–39, in Cumulative Index to Vols. 1–10 of *Journal* (see below); years 1939–48 to be included in Cumulative Index to Vols. 11–20.

Publication information: References constitute a department in the *Journal of the Acoustical Society of America* published biomonthly for the Society by the American Institute of Physics, 57 East 55th Street, New York 22, New York. Price of *Journal* per year is $7.25 to U. S. and Canadian members of the Society, $8 to other members, $10 to U. S. and Canadian nonmembers, $11 to other nonmembers.

2. *Aero-France, Revue*

Description: Periodical coverage is selective of articles of aeronautical interest. Abstracts are indicative, usually without criticism of the original and prepared by experts in the field. Government documents in aeronautics also are included.

Magnitude(approx): 2600 abstracts per year; 60 journals.

Indexes: One cumulative index appeared in 1944.

Publication information: Abstracts constitute a department called "Les Fiches Aeronautiques" in *Revue Aero-France* published monthly by the Aero Club de France, Service du Centre de Documentation Aeronatique Internationale, 6 rue Galilee, Paris, 16e, France. Price per year is 800 fr.

3. *Aeronautical Library Magazine Index, Pacific*

Description: Service provides a card index (no abstracts) which is selective of articles of interest to aeronautical engineers.

Magnitude (approx): 5000 articles and 2500 reports per year; 170 journals.

Indexes: Not applicable.

Publication information: The *Pacific Aeronautical Library Magazine Index* is issued on a weekly basis by the Pacific Aeronautical Library of the Institute of the Aeronautical Sciences, 7660 Beverly Blvd., Los Angles 36, California. Subscribing aircraft companies receive the cards automat-

ically; information regarding receipt by individuals and libraries should be obtained from the publisher.

4. Aeronautical Reviews*

Description: Periodical coverage is selective of papers of current aeronautical engineering interest. Abstracts are for the most part informative, staff-written, and without critical review. Book reviews are carried in a separate section of the journal.

Magnitude (approx): 5500 abstracts per year; 175–200 technical journals and 100 house organs.

Indexes: None in journal; an annual index volume is issued.

Publication information: "Aeronautical Reviews" constitutes a department in the *Aeronautical Engineering Review* published monthly by the Institute of the Aeronautical Sciences, Inc., 2 East 64th Street, New York 21, N. Y. Price per year of the *Review* is $3 in the U. S., $3.50 in foreign countries.

5. *Aeronauticus, Index*

Description: Periodical coverage is selective for important articles relevant to aeronautical research, development, production, and operation. Abstracts are semi-informative and without critical review; they usually are written by professional staff abstractors but sometimes by authors or other subject experts. Books, translations, pamphlets, reprints, and government publications also are covered.

Magnitude (approx): 1500 abstracts per year; 300 journals.

Indexes: None.

Publication information: Index Aeronauticus is published monthly by Ministry of Supply, TPA3/TIP, Thames House, Millbank, London S.W. 1, England. There is no automatic distribution but some copies are sent in exchange for other journals. Individuals should apply to the publisher.

6. *Aircraft Engineering**

Description: Coverage is in the field of aeronautics with nonperiodic reports and other separates being stressed rather than conventional journal papers. Emphasis is on British and Dominion publications. Abstracts vary from indicative to informative and are arranged in the journal under country of source.

Magnitude (approx): 300 abstracts per year.

Indexes: Annual, by country of source.

Publication information: Abstracts constitute a section ("Research Reports and Memoranda") in *Aircraft Engineering* published monthly by Bunhill Publishers, Ltd., 12 Bloomsbury Square, London, W.C. 1, England. Price per year is 30s.

7. *Aluminium Laboratories Limited, Abstract Bulletin of*

Description: Periodical coverage is selective for articles pertaining to aluminum and other light metals; material covered sufficiently previously is not treated unless it contains new or expanded information. Abstracts are informative except in cases where it is believed readers will have ready access to the original papers. They are written by staff abstractors and contain no critical review. Suitable, nonperiodical material received in the Laboratory library also is covered.

Magnitude (approx): 2000 abstracts per year; 275 journals.

Indexes: Monthly and annual author and subject.

Publication information: The *Abstract Bulletin of the Aluminium Laboratories Limited* is published monthly by the Laboratories, Box 84, Kingston, Ontario, Canada. Although intended primarily for the Aluminum Limited group of companies, the *Bulletin* receives limited complimentary distribution among individuals, firms, and institutions interested in the progress and technology of the light metals industry. Information regarding this distribution should be obtained from the editor.

8. *Ansco Abstracts*

Description: Periodical coverage is selective, the criterion being reasonably direct connection with Ansco's photographic products and research. Abstracts mostly are informative, without critical review and written by the editor. Their primary function is to serve the Ansco staff. Patents and governement reports also are covered.

Magnitude (approx): 800 abstracts per year; 75 journals.

Indexes: Annual author and subject.

Publication information: Ansco Abstracts is published monthly by Ansco, Binghamton, New York. The publication is not offered for sale on a subscription basis; information regarding limited gratis and exchange distributions should be obtained from the editor.

9. *Applied Mechanics Reviews*

Description: Periodical coverage is selective for articles on research in applied mechanics. Abstracts are informative, include critical review, and are written by subject specialists. Books, serials, and miscellaneous other publications also are covered.

Magnitude (approx): 1800 abstracts per year; 400 journals.

Indexes: Annual author, subject, periodical and abstractor.

Publication information: Applied Mechanics Reviews is published monthly by the American Society of Mechanical Engineers; editorial offices are at the Illinois Institute of Technology, 3300 Federal Street, Chicago 16, Illinois. Price per year is $9 to members of the Society and of other cooperating organizations, $12.50 to others.

10. *Batiment et des Travaux Publics, Annales de l'Institut Technique du**

Description: Publication appears in several separate sections, one of which is regularly entitled "Documentation Technique" and contains, in addition to the main body of abstracts, further subdivisions on translations, bibliographies, patents, and standards. Periodical coverage is apparently comprehensive for articles on all phases of building, including basic research in sciences that concern this field.

Magnitude: Over 5000 abstracts per year.

Indexes: Annual author and subject.

Publication information: The *Annales de l'Institut Technique du Batiment et des Travaux Publics* is published monthly, except July and August, by the Institut Technique du Batiment et des Travaux Publics, 28 boulevard Raspail, Paris 7e, France. Subscription rates for the "Documentation Technique" section should be obtained from the publishers.

11. *Battelle Library Review*

Description: Periodical coverage is selective on the basis of Battelle interest which include fundamental and applied research in chemistry, physics, fuels and combustion, ceramics, agriculture, graphic arts, metallurgy, and related technologies. Abstracts are indicative, without critical review, and written by professional abstractors who are trained scientists. Miscellaneous books and pamphlets also are covered.

Magnitude (approx): 15,000 abstracts per year; 800 journals.

Indexes: None.

Publication information: Battelle Library Review is published monthly by Battelle Memorial Institute, 505 King Avenue, Columbus 1, Ohio. Distribution is controlled and journal is not offered for sale on a subscription basis.

12. *Biological Abstracts*

Description: Periodical coverage is comprehensive for articles in the fields of biology, experimental medicine, and agriculture. Abstracts are issued in nine sections as follows: General Biology; Basic Medical Sciences; Microbiology, Immunology and Parasitology; Plant Sciences; Animal Sciences; Animal Production and Veterinary Science; Food and Nutrition Research; Human Biology; Cereals and Cereal Products. Abstracts are informative, without critical review and written by authors and volunteer abstractors who are subject experts. Books, patents, films, new apparatus, government and experiment station publications also are covered.

Magnitude (approx): 26,000 abstracts per year (1948); 2450 journals.

Indexes: Annual author, subject, geographic, systematic, and geologic.

Publication information: Biological Abstracts is published ten times a year by Biological Abstracts, 3613 Locust Street, Philadelphia 4, Pennsylvania. Price of complete publication is $40 per year; its nine sections can be subscribed to separately at prices ranging from $5 to $10 per year.

13. *British Abstracts*

AI General, Physical and Inorganic Chemistry; AII Organic Chemistry; AIII Physiology, Biochemistry, Anatomy, Pharmacology and Experimental Medicine; BI Chemical Engineering and Industrial Inorganic Chemistry Including Metallurgy; BII Industrial Organic Chemistry; BIII Agriculture, Foods and Sanitation; and C Analysis and Apparatus. (Of these, AI, BI and C are of most interest to physicists and details of these three only are presented below.)

Description: Periodical coverage is comprehensive for papers reporting original research and for review articles. Abstracts are indicative, without critical review and written by subject experts. Patents and government publications also are covered. Abstracts are available printed on one side of page only.

Magnitude (approx): Abstracts per year—Section AI (1948), 2435; Section BI (1948), 5751; Section C (1948), 2513; about 1600 journals.

Indexes: Annual and five-year author, subject, and formula.

Publication information: The sections of *British Abstracts* described above are published monthly by the Bureau of Abstracts, 9–10 Saville Row London, W. 1, England. They are sent gratis to members of supporting societies; annual subscription prices to others are AI £2 BI £3 and C £1 10s.

14. *Building Science Abstracts*

Description: Periodical coverage is comprehensive for articles of building and building materials, theory of structures, housing, plumbing, heating and ventilation, lighting, and sound insulation. Abstracts mostly are informative, without critical review and written by professional staff abstractors. Books, patents, government publications, and miscellaneous pamphlets also are covered.

Magnitude (approx): 1800 abstracts per year; 350 journals.

Indexes: Annual author and subject.

Publication information: Building Science Abstracts is published monthly by His Majesty's Stationery Office, York House, Kingsway, London, W.C. 2, England. Staff members of the Building Research Station receive the journal regularly for official use. Price per year to others, through either H.M.S.O. or a book dealer, is 24s.

15. *Buletin de Documentare Tehnica*

Description: Periodical coverage is comprehensive of articles of interest and importance to Roumanian industry. Abstracts are mixed informative and semi-informative, without critical review, and written by subject experts. Books and patents also are covered.

Magnitude (approx): 6000 abstracts per year; 600 journals.

Indexes: None.

Publication information: Buletin de Documentare Tehnica is published monthly by the Roumanian Institute of Bibliography, Documentation and Technical Publishers, a government enterprise at Street Gabriel Peri No. 3, Bucharest, Roumania. Journal is received by all government industrial enterprises; price to individuals is 1600 lei per year.

16. *Bulletin Analytique**

Description: Periodical coverage is apparently comprehensive of articles in the physical and biological sciences. Abstracts are usually of the indicative type and are arranged in the text under subject headings according to the

Universal Decimal Classification. The journal is issued in two sections; Part 1 deals with mathematics, physics, and chemistry and Part 2 with biology, physiology, and zoology.

Magnitude (approx): 50,000 entries per year; 3500 journals.

Indexes: No current information.

Publication information: Bulletin Analytique is published in two parts by the Centre du Documentation de Centre National de la Recherche Scientifique (C.N.R.S.), 18 rue Pierre-Curie, Paris 5e, France. Price per year of each of the two sections is 4000 fr.

17. *Bulletin Mensuel Signalêtique*

Description: Periodical coverage is selective of articles dealing wholly or partially with aeronautical subjects and techniques. Abstracts are indicative, without critical review of the original and are prepared by professional abstractors on the staff. Books, reports, patents, standards, and translations also are covered.

Magnitude (approx): 10,000 abstracts per year; 800 journals.

Indexes: None.

Publication information: Bulletin Mensuel Signalêtique is published monthly by the Service de Documentation et d'Information Technique (S.D.I.T.), 4 rue de la Porte d'Issy, Paris 15e, France. Price per year is 3800 fr.

18. *Bygglitteratur—Building Literature*

Description: Periodical coverage is selective for articles on building and building materials, and tests and research information on latter. Abstracts are informative, without critical review and written by professional abstractors and experts in the subject fields. Books, government publications, and pamphlets also are covered.

Magnitude (approx): 1800 abstracts per year; more than 250 journals.

Indexes: None.

Publication information: Bygglitteratur—Building Literature is published monthly by *Bygglitteratur*, Sturegatan 20, Stockholm, Sweden; price outside Sweden is 3 kr. per copy, 32 kr. per year for regular edition, 42 kr. per year including edition printed on one side of page only.

19. *Carrier Corporation Engineering Library Monthly Bulletin*

Description: Periodical coverage is selective for articles pertinent to the Corporation's research interests in aerodynamics, acoustics, air conditioning, engines, fluid flow, fuels, metals, refrigeration, temperature control, thermodynamics, and others. Abstracts are indicative, without critical review and written by the librarian.

Magnitude (approx): 1000 abstracts per year; 200 journals.

Indexes: None to date.

Publication information: Carrier Corporation Engineering Library Monthly Bulletin is published by the Corporation, 300 S. Geddes Street, Syracuse 1, New York. It is not offered for sale upon a subscription basis but copies are available upon request.

20. Ceramic Abstracts (British)

Description: Periodical coverage is comprehensive for articles relating to ceramic science and technology. Abstracts are informative, usually without critical review, and mostly written by professional abstractors although author abstracts are used when suitable and some are prepared by research ceramicists. British and U. S. patents, government publications and miscellaneous pamphlets also are covered.

Magnitude (approx): 2500 abstracts per year; 250 journals.

Indexes: Annual author and subject.

Publication information: Abstracts constitute a department in *Transactions of the British Ceramic Society* published monthly by the Society, Mellor Laboratories, Hanley, Stoke-on-Trent, England. Journal is sent gratis to members; price to nonmembers is £ 3 10s per year.

21. Ceramic Abstracts (U.S.)

Description: Periodical coverage is comprehensive for articles dealing with various phases of the ceramic industry including abrasives; cements, limes and plasters; enamel; glass; refractories; structural clay products, and whiteware. Abstracts vary from indicative to informative, include no critical review, and are written by Society members, librarians and others. Books, patents, and miscellaneous other publications also are covered.

Magnitude (approx): 3500 abstracts per year; 500 journals.

Indexes: Annual author and subject.

Publication information: Abstracts constitute a department in the *Journal of the American Ceramic Society*, published monthly by the Society, 2525 N. High Street, Columbus 2, Ohio. Journal is sent gratis to members; price to nonmembers is $15 per year.

22. *Chemical Abstracts*

Description: Periodical coverage is comprehensive for articles containing new information of chemical interest. Abstracts are informative, without critical review, and written almost exclusively by experts in the fields covered. Patents are covered; books, bulletins and the like are abstracted if they contain new information. Strong emphasis is placed on thorough indexing. Photocopying service is offered for papers abstracted.

Magnitude (approx): 50,000 abstracts per year; 4500 journals.

Indexes: Annual author, subject, formula, numerical patent and organic ring; decennial author and subject beginning 1907; collective formula and numerical patent in preparation.

Publication information: Chemical Abstracts is published semimonthly by the American Chemical Society with editorial offices at The Ohio State University, Columbus 10, Ohio. Price per year is $10 to members of A.C.S., $20 to nonmembers.

23. *Chemisches Zentralblatt**

Description: Periodical coverage is comprehensive for technical articles of chemical interest. Abstracts are informative and usually give data in great detail.

Magnitude (approx): 10,000 abstracts per year.

Indexes: Author in each issue; no recent information on subject or formula indexes.

Publication information: The *Chemisches Zentralblatt* is published bimonthly. Inquiries should be addressed to the Akademie-Verlag G.m.b.H., Berlin N. W. 7, Germany.

24. *Chimie et Industrie**

Description: Periodical coverage is selective of articles in the field of chemical industry, its basic research and applications.

Magnitude (approx): 1000 abstracts per year.

Indexes: No information.

Publication information: Chimie et Industrie is published monthly at 28, rue Saint Dominique, Paris 7e, France, with the technical collaboration of the Société de Chimie Industrielle. Subscription information should be obtained from the publisher.

25. *Coal Utilisation Research Association Monthly Bulletin, British*

Description: Periodical coverage is selective for articles dealing with new or newly authenticated matter on coal utilisation. Abstracts are indicative without critical review, and as far as possible written by subject experts. Some patents also are abstracted and a few book reviews are presented.

Magnitude (approx): 1800 abstracts per year; 250 journals.

Indexes: Annual author and subject.

Publication information: Abstracts constitute a department in the *British Coal Utilisation Research Association Monthly Bulletin* published by the Association, Randalls Road, Leatherhead, Surrey, England. Bulletin is sent gratis to member firms of the Association and their nominees; literature exchange agreements are made with other technical journals. Price to foreign postal subscribers is 20s. per year.

26. *Coil Spring Journal*

Description: Periodical coverage is comprehensive for articles of interest to spring makers and users, and to the wire industry. Abstracts are semi-informative, without critical review and written by the editor together with research assistants. Books, some patents, government publications, and miscellaneous pamphlets also are covered.

Magnitude (approx): 250 abstracts per year; 24 journals, supplemented by abstracts obtained from other abstracting services.

Indexes: Intend to issue three per year.

Publication information: Abstracts constitute a department in *Coil Spring Journal*, published quarterly by the Coil Spring Federation Research Organization, 20 Buckingham Gate, London, S.W. 1, England. The journal is distributed confidentially to members and associate members of the C.S.F.R.O.; it is not offered for sale on a subscription basis.

27. *Concrete Institute, Journal of the American*

Description: Coverage includes periodicals and books pertaining to the field of concrete. Abstracts vary from indicative to informative depending upon the probable availability of the original article to the reader. Abstracts may include critical review and are written by volunteer readers.

Magnitude (approx): 175 abstracts per year; 15 journals.

Indexes: Annual title, included in the *Proceedings* of the A.C.I.

Publication information: Abstracts constitute a department ("Current Review") in the *Journal of the American Concrete Institute* published monthly, September through June, by the Institute, 717 New Center Building, Detroit 2, Michigan. Price per year of Journal is $10.

28. *Corrosion*

Description: Periodical coverage is comprehensive; abstracts pertaining to corrosion and its prevention are selected from ones contributed by various companies, government agencies and abstract journals. Abstracts divide into about a fourth indicative, a half semi-informative and a fourth informative. Books, government publications and miscellaneous pamphlets also are covered.

Magnitude (approx): 1200 abstracts per year in journal; 2000 in annual publication (see below).

Indexes: Annual publication is indexed.

Publication information: Abstracts constitute a department of *Corrosion*, published monthly by the National Association of Corrosion Engineers, 910 Milam Building, Houston 2, Texas. There is also an annual abstract publication called *Bibliographic Survey of Corrosion.* Journal is sent gratis to members of the Association; price per year to others is $7.50. *Bibliographic Survey* is obtainable from the N.A.C.E. office at $4 for members, $5 for nonmembers.

29. *C.S.I.R. Information: Library Accessions List* (South Africa)

Description: Listing is comprehensive for books, pamphlets, reports and reprints of periodical articles received and processed by the Council's library. Abstracts are usually in the form of indicative annotations, occasionally contain critical review and are staff written.

Magnitude (approx): 200 items per month.

Indexes: None.

Publication information: C.S.I.R. Information: Library Accessions List is published monthly by the Library and Information Division, South African Council for Scientific and Industrial Research, P. O. Box 395, Pretoria, South Africa. It is available upon request on a restricted basis.

30. *Diamond Applications, Bibliography of Industrial*

Description: Periodical coverage is selective for articles on industrial diamonds, their applications and related sub-

jects. Abstracts are semi-informative, without critical review and written by subject experts. Patents, new patent specifications, government publications and miscellaneous pamphlets also are covered.

Magnitude (approx): 2800 abstracts per year; 330 journals.

Indexes: Monthly and annual name.

Publication information: Bibliography of Industrial Diamond Applications is published monthly by the Industrial Diamond Information Bureau, Industrial Distributors (Sales) Ltd., 32–34 Holborn Viaduct, London E.C. 1, England. It is sent gratis to all interested firms, institutions, societies, and individuals upon application to the Bureau.

31. *Dioptric Review and British Journal of Physiological Optics*

Description: Periodical coverage is comprehensive of articles on ophthalmic optics and kindred subjects of interest to optometrists. Abstracts are informative, without critical review and written by staff abstractors who also are subject experts. Government publications occasionally are covered.

Magnitude (approx): 90 abstracts per year; 50 journals.

Indexes: None at present; author index under consideration.

Publication information: Dioptric Review and British Journal of Physiological Optics is published quarterly by the British Optical Association, 65 Brook Street, London, W. 1, England. Price of journal is £ 2 2s per year.

32. *Documentation Technique**

Description: Periodical coverage is apparently comprehensive for technical articles on all aspects of electricity. Abstracts are of all classes. Sections on congress and conference proceedings are included, as well as translations, standards, and bibliography.

Magnitude: Over 2000 abstracts per year.

Indexes: No information.

Publication information: Documentation Technique is published bimonthly under the direction of the Centre de Documentation, 3 rue de Messine, Paris 8e, France. Subscription information should be obtained from the publisher.

33. *Dyers and Colourists, Journal of the Society of**

Description: Coverage is selective of papers pertinent to Society interest in the fields of plant and machinery; oils, detergents and wetting agents; bleaching, sizing and finishing materials; organic raw materials; coloring matters; textiles, paper, leather, rubber and plastics; dyeing processes; printing; analysis and testing. Patents also are covered.

Magnitude (approx): 3000 abstracts per year.

Indexes: Annual.

Publication information: Abstracts constitute a department in the *Journal of the Society of Dyers and Colourists*, published monthly by the Society, Ocean Chambers, 32–34 Picadilly, Bradford, Yorkshire, England. Price per year to nonmembers is £ 3 for the entire journal; £ 1 for abstracts only, printed on one side of paper.

34. *Electrical Engineering Abstracts (Science Abstracts, Section B)*

Description: Periodical coverage is comprehensive for publicly-available literature believed to have a reasonable possibility of making a serious contribution, however small, to the advancement of electrical engineering practice. Abstracts are semi-informative, without critical review and written in general by nonstaff subject experts; authors' abstracts are frequently used for articles in first rank journals. Although no type of publication is barred from consideration, chief attention is given to periodicals. Patents are not covered at present.

Magnitude (approx): 3000 abstracts per year; 400 journals.

Indexes: Annual author and subject; decennial under consideration.

Publication information: Electrical Engineering Abstracts (Science Abstracts, Section B) is published monthly by The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C. 2, England. Reduced rates are granted members of the Institution, the American Institute of Physics, and a few other organizations; price to others is 35s per year. Cost of combination subscription with *Physics Abstracts (Science Abstracts, Section A)* is 60s. per year.

35. *Electrical Research Association Weekly Abstracts**

Description: Coverage is selective in the direction of industrial applications of power and includes such topics as circuit theory, dielectric phenomena, discharges in gases, electric traction, electrical instruments and measurements, gas turbines, heating and ventilating, insulating materials, magnetism, rectifiers, rural electrification, steam power plants, telephone, and theory of communication.

Magnitude (approx): 1800 abstracts per year.

Indexes: None.

Publication information: Electrical Research Association Weekly Abstracts is published by the British Electrical and Allied Industries Research Association, Information Bureau, Thorncraft Manor, Dorking Road, Leatherhead, Surrey, England. It normally is distributed only to members of the Association; price per year is £1 5s.

36. *L'Électricité, Revue Générale de**

Description: Periodical coverage is comprehensive for articles of interest to workers in the electrical sciences, both pure and applied. Abstracts are informative and arranged under general subject headings.

Magnitude (approx): 1000 abstracts per year.

Indexes: No information.

Publication information: Revue Générale de L'Électricité is issued monthly by the Comité Electrotechnique Francais and the Union Technique de l'Électricité, 12 Place Henri Bergson, Paris 8e, France. The section containing the abstracts is published under separate cover as an insert to the *Revue*. Price per year for the entire journal is $12.

37. *Electronic Engineering Master Index**

Description: Service provides a bibliographical listing of research in electronics, optics, physics, and allied fields. Complete file of volumes provides a comprehensive source of information in electronics from 1925 to present. Also given are listings of declassified documents available from U. S., Canadian and British Governments and listings of patent references. A separate *Electronic Engineering Patent Index* also is published.

Magnitude: In 1947–48 volume, over 13,000 listings of articles in 234 journals and proceedings.

Indexes: Service is an index listing articles under some 400 subject headings.

Publication information: Electronic Engineering Master Index is published by Electronics Research Publishing Co., Inc., 480 Canal St., New York 13, N. Y. Prices of available volumes are as follows: 1925–45—$17.50; 1935–45—$10; 1946—$14.50; 1947–48—$19.50; 1949—$17.50. Prices of the *Patent Index* are: 1946—$14.50; 1947–48—$19.50; 1949—$14.50.

38. *Electroplating and Metal Finishing*

Description: Periodical coverage is selective, the criterion being importance to workers in the electroplating field. Abstracts vary from indicative to informative depending on Journal's estimate of the article's value; they are written by professional abstractors and may be critical of the original paper. Patents also are covered.

Magnitude (approx): 1500 abstracts per year; 200 journals.

Indexes: Annual author, subject and patent number.

Publication information: Abstracts constitute a department ("Abstracts from the World's Technical Press") in *Electroplating and Metal Finishing*, published monthly by Electroplating, 83 Udney Park Road, Teddington, Middlesex, England. Price of journal is 37s 6d or $8 per year.

39. *L'Elettrotecnica*

Description: Periodical coverage is selective of articles on practical and scientific electricity. Abstracts are informative, without critical review, and written by subject experts.

Magnitude (approx): 500 abstracts per year; 50 journals.

Indexes: Annual author and subject.

Publication information: Abstracts constitute a department in *L'Elettrotecnica*, published monthly by Associazione Elettrotecnica Italiana, via San Paolo, 10, Milano, Italy. Journal is sent gratis to members of the A.E.I.; subscription price outside Italy is 6000 lira per year.

40. Engineering Index

Description: Periodical coverage is selective for articles having sufficient technical information to be of interest to engineers and research workers. Abstracts are semi-informative, without critical review and written by staff abstractors who also are engineers in the fields dealt with. Books, government publications, experiment station bulletins and miscellaneous pamphlets also are covered. Photostats, microfilms or loan copies may be obtained under an agreement with the Engineering Societies Library, which is located at the same address as the *Index*.

Magnitude (approx): 25,000 abstracts per year; 1200 journals.

Indexes: Annual subject and author.

Publication information: Engineering Index is published in card form on a daily and weekly basis and annually in book form by Engineering Index, Incorporated, 29 West 39th Street, New York 18, New York. Information concerning subscription cost of the daily and weekly service, which is furnished in any combination of a large number of subject fields, should be obtained from the publisher. Price of the annual volume, which contains all abstracts issued during the year, is $50.

41. *Engineer's Digest*

Description: Periodical coverage is selective for articles of value to engineering progress. Abstracts are preponderantly informative although some are indicative. They are either author-written or prepared by other subject experts; some articles are reviewed critically on the editorial page. Photocopies of all abstracted papers are available. Books, institution papers, government publications, and miscellaneous pamphlets also are covered.

Magnitude (approx): 250 abstracts per year; 650 journals.

Indexes: Annual and five-year cumulative, author and subject.

Publication information: The Engineers' Digest is published monthly by Engineers' Digest Publications, Inc., 366 Madison Avenue, New York 17, New York. Price of journal is $7.50 per year.

42. *European Scientific Notes**

Description: Journal carries brief items which include both abstracts of articles and discussions of technical visits; criterion of selection is principally interest to ONR supported projects. Items are narrative-informative in type.

Magnitude (approx): 250 items per year.

Indexes: Annual title arranged under subject headings.

Publication information: European Scientific Notes is prepared in the Office of the Assistant Naval Attaché for Research, U. S. Embassy, London, and is distributed approximately monthly by the Naval Research Section, Science Division, Library of Congress, Washington 25, D. C. Distribution is restricted; requests for information should be sent to the Naval Research Section at the address given above.

43. *Excerpta Medica*

Description: Excerpta Medica is the collective title of a series of abstract journals in the medical field. Those covering material of interest to physicists are Section XII on Ophthalmology and Section XIV on Radiology. Abstracts are intended to cover all papers of importance in the fields specified. Product is informative in nature and written by specialists in the fields covered; some author abstracts are used. Occasional coverage is given books, theses, and monographs.

Magnitude (approx): In ophthalmology, 2500 abstracts per year and in radiology, 2000; about 1400 journals.

Indexes: Annual author and subject.

Publication information: Excerpta Medica is published monthly by Excerpta Medica, 111 Kalverstraat, Amsterdam—C, The Netherlands. Price per year for each of the two sections listed above—Ophthalmology and Radiology—is $15.

44. *Facts for Industry*

Description: Periodical coverage is selective for technical articles of interest to the business man, investor or newspaper editor. Material is taken from fields of food, chemicals, electronics, transport, fuel and power, and others. Abstracts attempt to interpret the aspects of the paper of interest to the groups mentioned rather than merely to summarize technical results; they are written by the editor and a small group of advisers. Government reports, learned society documents, research association bulletins and a few patents also are covered.

Magnitude: 600–1000 abstracts per year; 230 journals.

Indexes: None published; comprehensive index of references is maintained in the journal office.

Publication information: Facts for Industry is published monthly by A. E. Blake, Calderwood North, Wilmerhatch Lane, Epsom, Surrey, England. Price is £2 2s per year.

45. *Fonderie*

Description: Periodical coverage is limited to articles which concern the foundry industry, metallurgy of various alloys, and manufacture and installation of foundry equipment. Both informative abstracts of foreign papers (called "Notes Bibliographiques") and indicative summaries and references (called "Documentation Bibliographiques") are carried. Publications of the Association also are covered.

Magnitude (approx): Of Notes Bibliographiques, 40 abstracts per year; of Documentation Bibliographiques, 500 items per year.

Indexes: Annual author and subject to Notes Bibliographiques.

Publication information: Abstracts and references constitute departments in *Fonderie* published monthly by Centre Technique des Industries de la Fonderie, 12 Avenue Raphael, Paris XVI, France. Price of journal is 2500 fr. per year.

46. Foundry Abstracts

Description: Periodical coverage is comprehensive for articles bearing on the iron industry, the metallurgy of cast ferrous metals or cast iron from the consumer's point of view. Abstracts are indicative except where the subject is new or otherwise warrants informative treatment. They are prepared by a staff abtractor; papers are treated impartially and uncritically. Patents, standards, government publications, and miscellaneous pamphlets also are covered.

Magnitude (approx): 2000 abstracts per year; 150 journals.

Indexes: Biennial.

Publication information: Bulletin and Foundry Abstracts of the British Cast Iron Research Association is published bimonthly by the Association, Borderley Hall, Alvechurch, Birmingham, England. It is available through booksellers at £1 per year.

47. *Fuel*

Description: Periodical coverage is selective for material relating to fundamental fuel research. Abstracts appear in two departments—"Selected Abstracts" and "Recent Developments." Former are semi-informative and mostly drawn from and credited to other abstracting services; items under latter are informative and written by authorities in the field.

Magnitude (approx): Total for both groups, 360 abstracts per year; 50 journals.

Indexes: None.

Publication information: Fuel is published monthly by Butterworth's Scientific Publications, Ltd., 19 Ludgate Hill, London, E.C. 4, England. Price of journal per year is 25s in the United Kingdom, $6 in the United States.

48. *Gas Abstracts*

Description: Periodical coverage is reasonably comprehensive for articles on or related to the gas industry, and selective for papers on related industries like petroleum and coal. Analytical methods and general, physical, and organic chemistry are included. Abstracts have been semi-informative but, as space permits, are being made increasingly informative; they are without critical review and are written by subject experts. Pertinent books, pamphlets, and miscellaneous other publications also are covered. Photostats and microfilm of original articles are available for purchase.

Magnitude (approx): 2500 abstracts per year; 90 journals.

Indexes: Annual subject and author.

Publication information: Gas Abstracts is published monthly by the Institute of Gas Technology, 3300 S. Federal Street, Chicago 16, Illinois. It is sent gratis to associate member companies of the Institute, contributors to Institute programs and organizations with whom literature exchange agreements have been made; price to others is $15 per year.

49. *Geophysical Abstracts*

Description: Periodical coverage at present is comprehensive for literature pertaining to the exploration of natural resources and the investigation of geologic problems by geophysical methods; basic geophysical theory and research and related geological subjects are treated less fully. Plans to include all material on the physics of the solid earth are under consideration. Abstracts are informative, without critical review and staff-written unless the author's abstract is used. Books, patents, and miscellaneous other publications also are covered.

Magnitude (approx): 1000 abstracts per year; 300 journals.

Indexes: Quarterly and annual author; annual subject beginning 1949.

Publication information: Geophysical Abstracts is published quarterly by the Geological Survey, U. S. Department of the Interior, Washington 25, D. C. It is distributed on request to government agencies and officials and on an exchange basis to scientific institutions and nonprofit research organizations. Others may purchase copies at 25¢ each from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

50. *Geophysical Bulletin, Canadian*

Description: Abstract coverage is fairly comprehensive for periodicals, books, government publications, and miscellaneous pamphlets upon any phase of geophysics if published in Canada, and for Canadian geophysics regardless of where published; patents are not treated. Abstracts are semi-informative, usually without critical review, and written either by authors or by other subject experts. Associated publications include notes on current Canadian work in geophysics and bibliographies.

Magnitude: During 1948, 146 abstracts and bibliographies covering 312 titles.

Indexes: None.

Publication information: Canadian Geophysical Bulletin is published quarterly by the National Research Council of Canada, Ottawa, Ontario. It is not sold on a subscription basis; information regarding limited gratis distribution should be obtained from the editor.

51. *Geophysical Union, Transactions of American*

Description: Periodical coverage is selective for articles the editors judge to be of geophysical importance. Abstracts are semi-informative, occasionally with critical review, and written by the journal editors. Books also are covered.

Magnitude (approx): 25 abstracts per year; varying number of journals.

Indexes: Annual author and subject.

Publication information: Abstracts are part of *Transactions of the American Geographical Union* published bimonthly by the Union, 1530 P Street, N. W., Washington 5, D. C. Journal subscription is included in Union membership; price to nonmembers is $9 per year, $2 per number.

52. *Glaciology, Journal of*

Description: Periodical coverage is selective for articles containing new and valuable information of interest to glaciologists. Abstracts are semi-informative, without critical review and prepared by authors or other subject experts.

Magnitude (approx): 50 abstracts per year; 15 journals.

Indexes: None.

Publication information: Abstracts appear in the *Journal of Glaciology*, published twice a year (March and October) by The British Glaciological Society, 37B, Lowndes Street, London S. W. 1, England; price is 15s per year.

53. *Glass Technology, Journal of the Society of*

Description: Periodical coverage is selective for articles containing new knowledge relating to glass, fuels, furnaces, pyrometry, refractory materials, enamels, and such phases of plastics as bear on glass and its properties. Abstracts mostly are informative but vary according to the article being treated; they occasionally contain criticism and for the most part are written by subject experts.

Magnitude (approx): 900 abstracts per year; 120 journals.

Indexes: Annual author and subject.

Publication information: Abstracts constitute a department in the *Journal of the Society of Glass Technology* published bimonthly by the Society, "Elmfield," Northumberland Road, Sheffield 10, England. The *Journal* is sent gratis to Society members; price to others is 15s per issue or £3 15s per volume (unbound).

54. *Hiduminium Abstract Bulletin*

Description: Periodical coverage is selective for articles on properties of light metals and alloys, and the various techniques involved in their metallurgy. Abstracts mostly are informative, do not include critical review and are written by authors or by the editor. Patents, miscellaneous pamphlets, and occasional government publications also are covered.

Magnitude (approx): 500 abstracts per year; 200 journals.

Indexes: None.

Publication information: Hiduminium Abstract Bulletin is published bimonthly by High Duty Alloys Ltd., Trading Estate, Slough, Bucks., England. It is prepared primarily for the use of the issuing company and its staff; other interested individuals or organizations, however, may receive copies on request.

55. *Houille Blanche, Le* (Water Power)

Description: Periodical coverage is designed to keep the hydraulic engineer up to date on publications dealing with research of interest to him. Abstracts are semi-informative, sometimes include critical review and are written by subject experts. Unpublished reports, pamphlets and government documents also are covered.

Magnitude (approx): 1000 abstracts per year; 300 journals.

Indexes: None.

Publication information: Abstracts constitute a department in *Le Houille Blanche*, published eight times per year by Le Houille Blanche, B.P. 41, Grenoble, France. Price of journal is 4000 fr. per year.

56. *Hydromechanics Research Association, Bulletin of British*

Description: Periodical coverage is selective in field of hydromechanics. Topics treated include fluid mechanics, cavitation, hydraulic pumps and turbines, open-channel hydraulics, fluid meters, hydraulic servomechanisms.

Magnitude (approx): 400 abstracts per year.

Indexes: Annual.

Publication information: The *Bulletin of the British Hydromechanics Research Association* is published bimonthly by the Association, 79 Petty France, London,

S. W. 1, England. It is distributed gratis to members; information regarding other circulation should be obtained from the editor.

57. *Index to Current Technical Literature**

Description: Publication is an index which lists papers of interest to the technical staff of the issuing organization; items are presented under the major headings of chemistry, communication, engineering, general, mathematics, motion pictures, photography, and physics.

Magnitude: Over 10,000 items per year.

Indexes: No information.

Publication information: Index to Current Technical Literature is published monthly by the Technical Library, Publications Department, Bell Telephone Laboratories, Inc., 463 West Street, New York 14, N. Y. The *Index* is not offered for sale on a regular subscription basis; information regarding its circulation should be obtained from the publisher.

58. *Industrial Arts Index*

Description: This publication is a cumulative subject indexing journal. Its entries reflect a comprehensive coverage of semitechnical articles and a selective coverage of technical articles gleaned from periodicals in the fields of engineering, trade, and business.

Magnitude: No abstracts; many thousands of entries per year, some of which are very briefly annotated.

Indexes: Not applicable.

Publication information: The *Industrial Arts Index* is published in monthly cumulations, supplemented by an annual cumulation, by the H. W. Wilson Co., 950 University Ave., New York 52, N. Y. Subscription rates to individuals should be obtained from the publisher.

59. *Industrial Hygiene and Occupational Medicine, Archives of*

Description: Periodical coverage is selective for papers in industrial hygiene and occupational medicine, that is, toxicity of various substances, hygienic standards, case records, etc. Abstracts are both indicative and informative, frequently include critical review and are written by staff abstractors who are also subject experts. Books, patents, state, and federal documents sometimes are covered.

Magnitude (approx): 900 abstracts per year; 60 journals.

Indexes: Annual author and subject.

Publication information: Archives of Industrial Hygiene and Occupational Medicine is published monthly by the American Medical Association, 535 N. Dearborn Street, Chicago, Illinois. Editorial office is at 55 Shattuck Street, Boston 15, Massachusetts. Exchange arrangements are maintained with many other societies and journals; price to individuals is $8 per year.

60. *Instrument Research Association, Bulletin of British Scientific*

Description: Periodical coverage, in general, is selective on the basis of probable value to members of the Association and the journal's research staff. Fields of particular interest to physicists include electronics, heat, materials, optics, photoelectricity, photography, radioactivity, spectroscopy, vacuum techniques, and others. Abstracts are generally indicative, without critical review and written by staff members with scientific background. Books, reports and pertinent pamphlets also are covered.

Magnitude (approx): 2000 abstracts per year; 200 journals.

Indexes: Annual author and subject.

Publication information: The *Bulletin of the British Scientific Instrument Research Association* is published monthly by the Association, 17 Princes Gate, London, S. W. 7, England. It is sent gratis to Association members; price to others is $2 per year.

61. *Instruments Index**

Description: Publication is an index in three parts: (1) alphabetical list of instruments and apparatus, with the names of manufacturers provided under each heading; (2) a list of manufacturers specializing in laboratory supplies; (3) a directory of manufacturers, their addresses, and a brief description of the products handled.

Magnitude: Not applicable.

Indexes: Not applicable.

Publication information: Instruments Index is Part 2 of the July issue of *Instruments*, a monthly published by the Instruments Publishing Co., 921 Ridge Ave., Pittsburgh 12, Pennsylvania. Subscription rate $3 per year.

62. *Interplanetary Society, Journal of the British*

Description: Periodical coverage is comprehensive for articles on rocket engineering, chemical fuels, physiological problems of high speed flight, astronomical radar, and planetary conditions. Abstracts are informative, include critical review, and are written by subject experts.

Magnitude (approx): 200 abstracts per year; 300 journals.

Indexes: Annual author and subject.

Publication information: Abstracts constitute one department (and book reviews another) in the *Journal of the British Interplanetary Society* published bimonthly by the Society, 157 Friar Road, London, S. E. 15, England. Journal is sent gratis to Society members; price to others is $5 per year.

63. *Iron and Steel Institute, Journal of the*

Description: Periodical coverage is reasonably comprehensive for articles which deal with the manufacture, use and properties of iron and steel, or with ancillary subjects of interest to ferrous metallurgists. Abstracts vary between indicative and informative and, for the most part, are written by staff abstractors. All types of publication except patents are covered.

Magnitude (approx): 4800 abstracts per year; 750 journals.

Indexes: Annual and decennial author and subject.

Publication information: Abstracts constitute a department ("Abstracts of Current Literature and Book Notes") in the *Journal of the Iron and Steel Institute* published monthly by the Institute, 4 Grosvenor Gardens, London, S. W. 1, England. Journal is sent gratis to Institute members; price to nonmembers is £5 per year, postage extra. Exchange arrangements are made with other technical journals; reduced subscription rates are offered technical libraries.

64. *Kinematography, British*

Description: Periodical coverage is selective for articles containing information on kinematography and allied subjects including optics, sound and color films, sensitometry and others; particular reference is made to new developments. Abstracts are semi-informative, include critical review, and are written by subject experts. Books and patents are covered elsewhere in the journal.

Magnitude (approx): 110 abstracts per year; 25 journals.

Indexes: Cumulative from 1937 in preparation.

Publication information: Abstracts constitute a department in *British Kinematography* published monthly by the British Kinematograph Society, 53 New Oxford Street, London, W. C. 1, England. It is sent gratis to Society members; price to others is 37s 6d per year.

65. *Leather Chemists Association, Journal of the American*

Description: Periodical coverage is comprehensive for articles relevant to leather, tanning, skins, hides, and the like. Abstracts are of all types, without critical review and written by the editorial staff and outside abstractors. Books also are covered.

Magnitude: 300 abstracts per year; 25 journals.

Indexes: Annual author and subject.

Publication information: Abstracts constitute a department in the *Journal of the American Leather Chemists Association*, published monthly by the Association, c/o University of Cincinnati, Cincinnati 21, Ohio. The journal is sent gratis to Association members and exchange arrangements are made with other publications; subscription price is $12 per year.

66. *Leather Trades Chemists, Journal of the Society of*

Description: Periodical coverage is selective for articles in biology, chemistry, and physics which bear on the science of leather manufacture and testing. Abstracts are semi-informative, without critical review and written by subject experts. Book reviews, selected patents and miscellaneous pamphlets also are covered.

Magnitude (approx): 200 abstracts per year; 20 journals.

Indexes: Annual author and subject for entire journal.

Publication information: Abstracts constitute a department in the *Journal of the Society of Leather Trades Chemists* published monthly by the Society, "Craigieburn," Duppas Hill Road, Croydon, Surrey, England. Journal is sent gratis to members; price to nonmembers is 50s per year.

67. *Library Bulletin of Abstracts* (Universal Oil Products Co.)

Description: Periodical coverage is comprehensive for articles on petroleum research including studies of pure hydrocarbons, their reactions, properties and analytical methods used in their investigation; selective coverage is given material on petroleum refining, the petroleum industry, and petroleum products. Abstracts are informative, without critical review, and written by professional abstractors on the staff. Government publications and miscellaneous pamphlets are partially covered.

Magnitude (approx): 600 abstracts per year; 100 journals.

Indexes: Annual author and subject.

Publication information: Library Bulletin of Abstracts is published weekly by Universal Oil Products Company, 310 South Michigan Avenue, Chicago 4, Illinois. It is supplied automatically to members of the Petroleum Division of the American Chemical Society but is not offered for sale on a subscription basis; information regarding other gratis distribution should be obtained from the editor.

68. *Literatuuroverzicht* (KLM)

Description: Periodical coverage includes the general fields of aerodynamics, aeronautics, electricity, electronics, engines, hydromechanics, metals and metallurgy, photography, plastics, strength of materials, and stress analysis. Only author, title of article and reference are given. Books, patents, government publications, and miscellaneous patents also are covered. Annotations are printed on one side of page only to permit clipping and filing.

Magnitude (approx): 4000 abstracts per year.

Indexes: None.

Publication information: KLM—Literatuuroverzicht is published weekly by KLM—Royal Dutch Air Lines, Schiphol Airport, Amsterdam, Holland. It is prepared primarily for the use of KLM but individuals may be able to subscribe; information regarding price should be obtained from the editor.

69. Lithographic Abstracts

Description: Periodical coverage is selective for articles of technical or practical interest to lithographers and workers in allied fields. Abstracts vary in type, include no critical review and are prepared by authors and other subject experts. Books, patents, and miscellaneous pamphlets also are covered. Photocopies of original papers are available at 60¢ per page.

Magnitude (approx): 275 abstracts per year; 100 journals.

Indexes: None; an annual compilation is published.

Publication information: Editorial address is Lithographic Technical Foundation, Inc., 1800 South Prairie Street, Chicago 16, Illinois. Abstracts appear as departments in several monthly journals; these, together with their annual subscription prices, are: *National Lithographer*, $3; *Lithographer's Journal*, $2.50; *Modern Lithography*, $3; and *British and Colonial Printer*, 25s. The annual publication is sent gratis to Foundation members: price to others is $2 per copy.

70. *Magnesium Review and Abstracts*

Description: Periodical coverage is comprehensive for articles relevant to the production, fabrication, and use of magnesium and its alloys. Abstracts are semi-informative, include critical review, and are staff written. Books and miscellaneous separates also are covered as occasion arises.

Magnitude (approx): 30 abstracts per year; 30 journals.

Indexes: None.

Publication information: Magnesium Review and Abstracts is published on an average of twice a year by Magnesium Elektron Limited, 82 Piccadilly, London, W. 1, England. It is not offered for sale on a subscription basis; information regarding limited gratis distribution should be obtained from the publisher.

71. *Marine Engineers, Transactions of the Institute of*

Description: Periodical coverage is selective of materia- having a marine engineering bias. Abstracts are informal tive, without critical review, and written by part-time professional abstractors. Books, patents, government publications, and miscellaneous pamphlets also are covered.

Magnitude (approx): 650 abstracts per year; 100 journals.

Indexes: Annual subject.

Publication information: Abstracts constitute a department in *Transactions of the Institute of Marine Engineers,* published monthly by the Institute, 85 Minories, London, E. C. 3, England. Price of entire journal is $6 per year; of abstracting service alone, 25s.

72. *Mathematical Reviews*

Description: Periodical coverage is comprehensive for research papers in mathematics and mathematical physics. Abstracts are informative, without critical review, and, as far as possible, written by subject specialists; otherwise author abstracts or titles only are used. Books, government publications, and miscellaneous pamphlets receive some coverage.

Magnitude (approx): 5000 abstracts per year; 600 journals.

Indexes: Annual author and subject.

Publication information: Mathematical Reviews is published monthly (except August) by the American Mathematical Society with editorial offices at Brown University, Providence 12, Rhode Island. Price to members of sponsoring societies is $10 per year, to others $20.

73. *Mathematical Tables and Other Aids to Computation*

Description: Periodical coverage is comprehensive of articles of mathematical value to colleges, universities, and research centers. Abstracts are informative, include critical review and are written by editors and other experts in the fields covered. Errors in computation are pointed out; historical surveys of previous work occur in reviews and independent notes. Books, government publications, and miscellaneous pamphlets also are covered to some extent.

Magnitude (approx): 170 abstracts per year; several hundred journals.

Indexes: Biennial.

Publication information: Abstracts constitute a part of *Mathematical Tables and Other Aids to Computation,* published quarterly at the National Research Council, 2101 Constitution Avenue, Washington 25, D. C. Price of the journal is $5 per year.

74. *Mathematik, Zentralblatt Für**

Description: Periodical coverage is apparently comprehensive for technical articles in the field of mathematics. Abstracts are informative.

Magnitude: Over 2500 per year.

Indexes: Author in each issue; semiannual author and subject.

Publication information: The *Zentralblatt für Mathematik* is published bimonthly by the Deutsche Akademie der Wissenschaften zu Berlin, Forschungsinstitut für Mathematik, Berlin, N. W. 7, Unter den Linden 8, Germany. Subscription information should be obtained from the publishers.

75. *Medical Literature, Current List of*

Description: Is a listing rather than an abstracting service. Coverage is selective for material published during the six months preceding the list date. Serial publications on medicine and related sciences, in all languages, are included.

Magnitude (approx): 73,000 articles listed per year; 2000 journals.

Indexes: Monthly subject.

Publication information: Current List of Medical Literature is published weekly by the Army Medical Library, 7th Street and Independence Avenue, S. W., Washington 25, D. C. It is sent gratis to a number of government agencies and activities and on exchange to institutions issuing publications of interest to the Library. It may be purchased from the Superintendent of Documents, Washington 25, D. C. at 10¢ per copy or $3 per year (foreign $3.75).

76. *Medicona Aeronautica, Rivista di*

Description: Periodical coverage is selective of articles dealing with the physiology, pathology, psychology, and hygiene of man in flight and with related subjects. Abstracts are largely informative, may include criticism of the original and are prepared by experts in the fields covered. Books also are included.

Magnitude (approx): 250 abstracts per year; 30 journals.

Indexes: Annual author and subject.

Publication information: Rivista di Medicona Aeronautica is published quarterly by the Ministero della Difesa-Aeronautica, Via P. Gobetti, 2 Rome, Italy. Subscription information should be obtained from the publisher.

77. Metal Literature, A. S. M. Review of

Description: Coverage is comprehensive for articles of "metals" interest. Abstracts are indicative, without critical

review, and written by professional abstractors with technical training. Some coverage is given to books and miscellaneous other publications. Abstracts mailed on 15th of any month cover all source material received by 25th of preceding month. Abstracts are accumulated annually in an indexed, bound volume.

Magnitude (approx): 9000 abstracts per year; 400 journals.

Indexes: Annual author and subject, in bound volume only.

Publication information: Abstracts constitute a department in *Metals Review* published monthly by the American Society for Metals, 7301 Euclid Avenue, Cleveland 3, Ohio. Journal is included with A.S.M. membership; price is $5 per year to U. S. nonmembers, $6 to foreign. Annual volume is $10 to members, $15 to others.

78. Metallurgical Abstracts

Description: Periodical coverage is comprehensive for articles pertaining to general and nonferrous metallurgy and of interest to members of the Institute of Metals; special emphasis is placed on coverage of metal physics. Abstracts are informative, may be critical of the original paper, and are written mainly by subject experts. Books, government publications, and miscellaneous pamphlets also are covered.

Magnitude (approx): 6000 abstracts per year; 1000 journals.

Indexes: Annual and decennial author and subject.

Publication information: Abstracts constitute a department ("Metallurgical Abstracts") in the *Journal of the Institute of Metals*, published monthly by the Institute, 4 Grosvenor Square, London, S. W. 1, England. The Abstracts are bound separately each year and have their own volume series. The monthly publication is sent gratis to Institute members; price to others is $20.25 per year including index and binder.

79. *Métallurgie, Revue de**

Description: Coverage of periodicals is selective of articles of technical interest to metallurgists.

Magnitude (approx): 150 abstracts per year.

Indexes: Annual author and subject.

Publication information: The *Revue de Métallurgie* is published monthly by the Société Francaise de Métallurgie, 5, Cite Pigalle, Paris 9e, France. Subscription rate outside France is 9500 fr. per year.

80. *Metal Powder Report*

Description: Periodical coverage is comprehensive for articles on metal powders, sintered products, and fundamentals of powder metallurgy. Abstracts are informative, without critical review and staff-written. A monthly editorial deals with outstanding developments in the field. Books, patents, government publications, and miscellaneous pamphlets also are covered.

Magnitude (approx): 350 abstracts per year; 80 journals.

Indexes: Annual author and subject.

Publication information: Metal Powder Report is published monthly by Powder Metallurgy, Ltd., Commonwealth House, 1–19 New Oxford Street, London, W. C. 1, England. Subscription information should be obtained from the publisher.

81. *Meteorological Abstracts and Bibliography*

Description: Periodical coverage is selective for articles pertinent to current research projects or of permanent value as contributions to meteorology. Abstracts are of all classes, occasionally contain criticism of the original and are prepared by professional abstractors on the journal staff. Each issue contains an annotated bibliography on some special subject field pertaining to meteorology. References in this section are accompanied by indicative abstracts. Books, government publications, pamphlets, and patents also are included.

Magnitude (approx): 4500 abstracts per year; 50 journals covered regularly and up to 500 scanned.

Indexes: Monthly author, corporate author, place, and subject.

Publication information: Meteorological Abstracts and Bibliography is published monthly by the American Meteorological Society, 5 Joy St., Boston, Mass. Price per year is $3.

82. *Metropolitan-Vickers Technical News Bulletin*

Description: Periodical coverage is selective for articles of interest to the Company's scientific, technical and design groups; pertinent subjects include acoustics, heat and thermodynamics, theoretical electricity, metallurgy and others. Abstracts are indicative, without critical review, and written by trained staff personnel.

Magnitude (approx): 1700 abstracts per year; 300 journals.

Indexes: None.

Publication information: The *Metropolitan-Vickers Technical News Bulletin* is published weekly by Metropolitan-Vickers Electrical Company, Ltd., Research Department, Trafford Park, Manchester 17, England. It is issued primarily for the use of the Company; information regarding restricted distribution to other organizations should be obtained from the editor.

83. *Microfilm Abstracts*

Description: Comprise a collection of abstracts of doctoral dissertations in all fields which are available in complete form on microfilm. Abstracts are indicative and author-written.

Magnitude: 175–225 theses abstracted per year.

Indexes: Triennial cumulative.

Publication information: Microfilm Abstracts is published semi-annually by University Microfilms, Ann Arbor, Michigan. It is distributed gratis to a selected list of domestic and foreign university and research libraries; purchase price is $1.25 per volume. Cost of microfilm of original manuscripts is 1½¢ per page.

84. *Microscopical Society, Journal of the Royal*

Description: Periodical coverage is comprehensive for articles on electron microscopy and selective for papers which deal with histological and cytological methods and new instruments and techniques in microscopy. Abstracts are informative, without critical review and written by subject experts.

Magnitude (approx): 250 abstracts per year; 500 journals.

Indexes: Annual author and subject.

Publication information: Abstracts appear in the *Journal of the Royal Microscopical Society*, published quarterly by the Society, B.M.A. House, Tavistock Square, London, W. C. 1, England. It is sent gratis to fellows of the Society; price to others is 42s per year.

85. Mineralogical Abstracts

Description: Periodical coverage is selective for articles on new data and methods, comprehensive for material on new minerals and meteorites. Abstracts are indicative for new data, terms and names, and informative for general articles; they are mostly without critical review and are written by subject experts. Books, geological surveys and reprints also are covered.

Magnitude (approx): 700 abstracts per year; journal coverage is scattered.

Indexes: Triennial author and subject.

Publication information: Abstracts constitute a department in the *Mineralogical Magazine*, published quarterly by the Mineralogical Society, London; publication address is Oxford University Press, Amen House, Warwick Square, London, E. C. 4, England. Journal is sent gratis to Society members; price to others is 40s per year.

86. *Mining and Metallurgy, Bulletin of the Institution of*

Description: Periodical coverage provides a comprehensive index of original articles in mining and metallurgy. Books, government publications, proceedings, reports, and miscellaneous pamphlets also are covered.

Magnitude (approx): 1800 index entries per year; 350 journals.

Indexes: None published; cumulative maintained in Institution library.

Publication information: Index constitutes a department ("Index of Recent Articles") in the *Bulletin of the Institution of Mining and Metallurgy* published monthly by the Institution, Salisbury House, Finsbury Circus, London, E. C. 2, England. Bulletin is sent gratis to Institution members; price to others is £3 per year.

87. *Monthly Abstract Bulletin* (Kodak)

Description: Periodical coverage is selective for articles of interest to the Kodak Research Laboratory's research and manufacturing divisions. Abstracts are of all types and are without critical review; they are written by subject experts, by authors and by others—all on the Laboratory staff. Books, patents, some government publications, and miscellaneous pamphlets also are covered.

Magnitude (approx): 2200 abstracts per year; 375 journals.

Indexes: Annual author.

Publication information: Monthly Abstract Bulletin is published by the Kodak Research Laboratory, Eastman Kodak Company, Rochester, New York. It is distributed gratis to employees of the company, and to certain outside individuals and organizations approved by the Laboratory; price to others is $3 per year.

88. *Motor Industry Research Association Bulletin*

Description: Periodical coverage is selective for articles of current technical interest to the motor industry; subjects treated include transport vehicles, fuels and lubricants, research methods and others. Abstracts in the monthly edition are informative; those in the quarterly are semi-informative. They contain no critical review and are written by both professional abstractors and by subject experts. Pamphlets from professional institutions, government agencies, and research organizations also are covered.

Magnitude (approx): 600 abstracts per year; 150 journals.

Indexes: None annually; subject index or contents list appears in each monthly bulletin.

Publication information: Abstracts are issued monthly in loose-leaf and as a department in the *Motor Industry Research Association Bulletin*, published quarterly by the Association, Great West Road, Brentford, Middlesex, England. Both editions are sent gratis to firms in the motor and allied industries in Great Britain; they are not normally available to nonmembers.

89. *Naval Propulsive Power*

Description: Periodical coverage is selective for research and development articles on engines for ships and aircraft. Abstracts are about one-fourth informative and three-fourths indicative, include critical review, and are written by subject experts. Government publications and numerous papers presented before technical societies also are covered.

Magnitude (approx): 500 abstracts per year; 100 journals.

Indexes: Annual subject included with June issue of journal.

Publication information: Naval Propulsive Power is issued monthly by the Power Branch, Assitant Chief for Research, ONR, U. S. Navy, Washington 25, D. C. Journal goes only to government activities selected by ONR and is not available to the general public; information regarding loan of the journal should be obtained from the issuing agency.

90. *Naval Research Laboratory Library Bulletin*

Description: Periodical coverage, although selective on the basis of NRL interest, actually is quite comprehensive because of the Laboratory's broad research program. Abstracts essentially are annotations intended only to show contents and scope; they are written by subject specialists. The Bulletin also serves as an NRL library accessions list for all documents including books.

Magnitude (approx): 16,000 abstracts per year; 450 journals.

Indexes: None published; a cumulative index is maintained at NRL.

Publication information: Naval Research Laboratory Library Bulletin is published weekly by Naval Research Laboratory, Washington 20, D. C. It is not offered for sale on a subscription basis; information regarding limited gratis distribution is obtainable from the librarian.

91. *New Technical Books*

Description: Service deals only with technical books. Coverage is comprehensive for titles published in the United States and pertaining to science and technology except medicine and the biological sciences; it is selective for books published in other countries. Reviews are semi-informative, occasionally are critical and are written by the editor and other librarian-specialists in scientific literature.

Magnitude (approx): 450 book reviews per year.

Indexes: Annual.

Publication information: New Technical Books is published bimonthly by the New York Public Library, Science and Technology Division, 5th Avenue and 42nd Street, New York 18, New York. Price of journal is $1.50 per year.

92. *Nickel Bulletin, The**

Description: Current information on nickel is summarized with abstracts grouped under headings which include cast iron, construction steels, electro-deposition, and other coating methods, heat and corrosion resisting alloys, metal physics, nickel-iron alloys and nonferrous alloys. Patents also are covered.

Magnitude (approx): 500 abstracts per year.

Indexes: Annual author and subject.

Publication information: The Nickel Bulletin is published monthly by The Mond Nickel Company, Ltd., Sunderland House, Curzon Street, London, W. 1. The *Bulletin* is not offered for sale on a subscription basis; information regarding gratis distribution should be obtained from the publisher.

93. *Non-Ferrous Metals Research Association, Bulletin of British*

Description: Periodical coverage is selective on the basis of importance in research and industrial activity in the field of nonferrous metals and their alloys. Abstracts are indicative or semi-informative, without critical review and written either by science graduates on the staff or by research specialists. Books, patents, and pertinent miscellaneous pamphlets also are covered.

Magnitude (approx): 2500 abstracts per year; 300 journals.

Indexes: Annual author and subject.

Publication information: The *Bulletin of the British Non-Ferrous Metals Research Association* is published monthly by the Association, 81–91 Euston Street, London, N. W. 1, England. It is sent gratis to Association members and to a number of large institutions and libraries; it is not offered for sale on a subscription basis.

94. *Nuclear Science Abstracts*

Description: Periodical coverage is of scientific fields in which research is being carried on under AEC sponsorship or contract. Abstracts are informative for published papers, indicative for books, patents, government publications and review articles, which also are covered; they are written by professional abstractors except where author's abstract is used.

Magnitude (approx): 4500 abstracts per year; 800 journals.

Indexes: Semimonthly (each issue) author, subject, and foreign geographic; semiannual cumulative, published separately.

Publication information: Nuclear Science Abstracts is published semimonthly by the Technical Information Branch, U. S. AEC; journal correspondence is handled by Document Sales Agency, P. O. Box 62, Oak Ridge, Tennessee. Journal is sent gratis to AEC installations and contractors and to certain other government agencies; price to others is $6 per year (24 issues).

95. *Oil Chemists Society, Journal of the American*

Description: Periodical coverage is selective for articles which concern the chemical, physical, technical and nutritious aspects of fats, oils and soaps. Abstracts are semi-informative, without critical review and written by members of the Society. Patents, government publications, and miscellaneous pamphlets also are covered.

Magnitude (approx): 1000 abstracts per year; 300 journals.

Indexes: None.

Publication information: Abstracts constitute a department in the *Journal of the American Oil Chemists Society* published monthly by the Society, 35 East Wacker Drive, Chicago 1, Illinois. Price of journal is $4 per year.

96. *Ophthalmology, American Journal of*

Description: Periodical coverage is comprehensive for articles of interest to the clinical ophthalmologist. Abstracts are informative, without critical review and written by experts practising in the field.

Magnitude (approx): 1500 abstracts per year; 50 journals.

Indexes: None.

Publication information: Abstracts constitute a department in the *American Journal of Ophthalmology* published monthly by Ophthalmic Publishing Company, 664 N. Michigan Avenue, Chicago 11, Illinois. Price of journal is $10 per year.

97. *Optique Théorique et Instrumentale, Revue de*

Description: Periodical coverage is selective for articles dealing with significant theories and applications in the field of optics. Abstracts are informative, may be illustrated, frequently include critical review and are written by subject experts. All available documents including patents are covered.

Magnitude (approx): 650 abstracts per year; 200 journals.

Indexes: Annual author and subject.

Publication information: Abstracts constitute a department in *Revue d'Optique Théorique et Instrumentale* published monthly by Editions de la *Revue d'Optique*, 3 Boulevard Pasteur, Paris, XV, France. Price is 1900 fr. per year (1949) in countries outside France.

98. *Paint, Colour, Varnish and Allied Industries, Review of Current Literature on*

Description: Periodical coverage is comprehensive for papers of scientific and technical interest to the paint, pigment, varnish, lacquer, and allied industries, including articles on oils, waxes, ink, solvents, soaps, resins, rubber, and others. Abstracts mostly are semi-informative, without critical review, and are written by senior scientists of the Research Association of British Paint, Colour and Varnish Manufacturers. All other types of published matter are also treated with particular emphasis being placed on wide geographic coverage. Photostats and loan copies are available to association members.

Magnitude (approx): 5000 abstracts per year; 140 journals, supplemented by abstract exchange with other abstracts services.

Indexes: Annual author and subject.

Publication information: Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries is published bimonthly by Chorley and Pickersgill, Ltd., Amberly House, Norfolk Street, Strand, London, W. C. 2, England; editorial address is Paint Research Station, Waldegrave Road, Teddington, Middlesex, England. The *Review* is sent gratis to Association members and on exchange to other journals. Subscription price is £3 3s per year.

99. *Pétrole, Revue de l'Institut Francais du*

Description: Periodical coverage is comprehensive for original papers on scientific and technical aspects of the petroleum industry, its derivatives and related industries. Abstracts are principally informative, include critical review, and are written by subject experts.

Magnitude (approx): 320 abstracts per year; 100 journals.

Indexes: Annual author and subject.

Publication information: Abstracts constitute a department in *Revue de l'Institut Francais du Pétrole et Annales des Combustibles Liquids*, published monthly by the Institut Francais du Pétrole, 2 rue de Lubeck, Paris XVI, France. Some exchange arrangements are made; price to subscribers outside France and its colonies is 2200 fr. per year.

100. *Petroleum Institute, Journal of the*

Description: Periodical coverage is comprehensive for articles dealing with petroleum technology in its widest sense, including oilfields exploration and exploitation, transport and storage, refinery operations, products, engines, and automotive equipment. Abstracts are informative, without critical review and written, as far as possible, by subject experts. Books and patents also are treated, the former in critical review fashion.

Magnitude (approx): 1900 abstracts per year; 50 journals regularly and 150 others irregularly.

Indexes: Annual author and subject.

Publication information: Abstracts constitute a department in the *Journal of the Institute of Petroleum*, published monthly by the Institute, 26 Portland Place, London, W. 1, England. Journal is sent gratis to Institute members; price to others is £3 13s 6d per year.

101. *Photographic Abstracts*

Description: Periodical coverage is selective on the basis of photographic interest, including science of photography, industrial and scientific applications, photoengraving, stereoscopy, kinematography, and others. British patents are covered comprehensively and U. S. patents almost so. Abstracts are semi-informative, without critical review, and written by subject experts. Pertinent, available books, government publications, and miscellaneous pamphlets also are covered.

Magnitude (approx): 1300 abstracts per year; 100 journals.

Indexes: Annual patent and author; decennial subject (except for break during war).

Publication information: Photographic Abstracts is published quarterly by The Royal Photographic Society of Great Britain, 16 Princess Gate, London, England. Price per year to Society members is 7s 6d quarterly or 30s per year.

102. *Photographiques, Science et Industries*

Description: Periodical coverage is selective for articles believed to be of real photographic significance. Abstracts are informative and, for the more important papers, may run to several pages, being essentially illustrated abridgements; they may include critical review and are written by subject experts. All other available pertinent publications also are covered.

Magnitude (approx): 600 abstracts per year; 200 journals.

Indexes: Annual subject.

Publication information: Abstracts constitute a department ("Revue de la Presse Technique et de la Presse Scientifique") in *Science et Industries Photographiques* published monthly by Editions de la *Revue d'Optique*, 3 Boulevard Pasteur, Paris XV, France. Price of journal per year (1949) for subscribers outside of France is 2500 fr.

103. *Physics Abstracts* (*Science Abstracts, Section A*)

Description: Periodical coverage is comprehensive for publicly available literature believed to have a reasonable possibility of making a serious contribution, however small, to the advancement of physics. Abstracts are semi-informative, without critical review and written, in general, by nonstaff subject experts; authors' abstracts are frequently used for articles in first-rank journals. Although no type of publication is barred from consideration, chief emphasis is placed on periodicals; patents are not covered at present.

Magnitude (approx): 7500 abstracts in 1949; 400 journals.

Indexes: Annual author and subject; decennial under consideration.

Publication information: Physics Abstracts (*Science Abstracts, Section A*) is published monthly by The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W. C. 2, England. It is sent gratis to members of The Physical Society (London) and of The American Physical Society; price to others is 35s per year. Cost of combination subscription with *Electrical Engineering Abstracts* (*Science Abstracts, Section B*) is 60s per year.

104. *Plastica*

Description: Periodical coverage is selective for articles of interest to the plastics industry. Abstracts are indicative, without critical review, and written by members of the Plastics Research Institute who are subject experts. Patents of Netherlands and Belgium also are covered.

Magnitude (approx): 500 abstracts per year; 30 journals.

Indexes: None.

Publication information: Abstracts constitute a department in *Plastica*, published monthly by the Plastics Research Institute, T.N.O., Julianalaan 134, Delft, Holland. Price per year is 10 guilders to Netherlands subscribers, 11 guilders to others.

105. Plastics Digest

Description: Periodical coverage is selective for articles on plastics production, properties and testing, and on high polymer chemistry; comprehensive coverage is given U. S. patents on plastic materials and their fabrication. Abstracts are indicative, without critical review, and written by professional abstractors who are experts in the fields they treat. Books, government publications, and miscellaneous pamphlets also are covered. An annual literature review in the January issue includes a comprehensive list of plastics articles published the preceding year together with a critical analysis of their contributions.

Magnitude (approx): 200 abstracts per year of articles, 500 of patents; 30 journals covered regularly and many others irregularly.

Indexes: Annual subject.

Publication information: Abstracts constitute a department in *Modern Plastics*, published monthly by Modern Plastics, Incorporated, 122 East 42nd Street, New York 17, New York. Price of journal is $5 per year.

106. *Plastics Federation Abstracts, British*

Description: Periodical coverage is comprehensive for articles on plastics and their applications. Abstracts are indicative or semi-informative, without critical review and written by staff abstractors. Patents and technical literature from plastics firms in Great Britain and the U. S. also are covered.

Magnitude (approx): 3000 abstracts per year; 80 journals.

Indexes: Annual author and subject.

Publication information: British Plastics Federation Abstracts is published monthly by the Federation, 47–48 Piccadilly, London, W. 1, England. It is sent gratis to Federation members; others may purchase copies upon application to the Federation.

107. *Plastics Trends*

Description: Periodical coverage is selective for articles relating to the origins, applications and processing of plastics. Abstracts are semi-informative, without critical review and written by subject experts.

Magnitude (approx): 400 abstracts per year; 30 journals.

Indexes: Index in each issue.

Publication information: Plastics Trends is published published monthly by the Plastics Industries Technical Institute, Division of West Coast University, 1601 South Western Avenue, Los Angeles, California. Price of the journal is $5 per year.

108. *Plating*

Description: Coverage includes abstracts and reviews of material of interest to workers in the plating field; it is selective for technical papers and trade literature but comprehensive for patents. Abstracts vary between indicative and informative with those of patents all being the latter; they are written by technically trained professional abstractors and occasionally include critical review.

Magnitude (approx): 450 abstracts per year of all kinds; 10 journals covered regularly, many others irregularly.

Indexes: None.

Publication information: Abstracts constitute several departments of *Plating* published monthly by the American Electroplaters' Society, P. O. Box 168, Jenkintown, Pennsylvania. Journal is sent gratis to Society members; price per year to others is $4 in the U. S. and Canada, $6 foreign.

109. *Prevention of Deterioration Abstracts*

Description: Periodical coverage is selective for papers giving current information on cause and prevention of deterioration of materials, components, and assemblies. Field-wise, abstracts cut across boundaries of biology, chemistry, metals, physics, plastics, textiles and others. Abstracts are informative, occasionally include critical review, and are written by professional scientists on staff. Patents and unpublished reports—domestic and foreign—also are covered. A monthly bibliography of reports received, called the Advance List, is published separately.

Magnitude (approx): 960 abstracts per year; 100 journals.

Indexes: Semiannual author and subject (at end of each volume); ten-volume cumulative in preparation.

Publication information: Prevention of Deterioration Abstracts is published monthly, in two volumes per year, by the Prevention of Deterioration Center, National Research Council, 2101 Constitution Avenue, Washington 25, D. C. Journal is distributed gratis to many government departments, universities, institutes and industrial laboratories doing research for defense agencies; price to others is $50 per year. Price of Advance List is $10 per year.

110. *Printing Abstracts*

Description: Periodical coverage is fairly comprehensive for articles of interest to the printing and allied trades. Abstracts are semi-informative, without critical review and written principally by professional staff abstractors; supplementary use is made of author abstracts. Section of interest to physicists is principally that on science and printing. Books, patents, catalogs, pamphlets, and government publications also are included. Originals or photocopies are loaned to members of the Association or to research institutes.

Magnitude (approx): 2000 abstracts per year; 200 journals.

Indexes: Annual author and subject.

Publication information: Printing Abstracts is published monthly by the Printing, Packaging, and Allied Trades Research Association, Patra House, Randalls Road, Leatherhead, Surrey, England. It is sent automatically on a confidential basis to members of the Association and is exchanged with other publications; it is not available at present on a subscription basis.

111. *Psychological Abstracts*

Description: Periodical coverage is comprehensive of papers having significance in all aspects of behavior; material of possible physics interest falls largely under vision and audition. Abstracts are semi-informative, without critical review, and written by collaborating experts in the subject fields. Books, government publications, miscellaneous pamphlets, and films also are covered.

Magnitude (approx): 5500 abstracts per year; 500 journals.

Indexes: Annual author and subject.

Publication information: Psychological Abstracts is published monthly by the American Psychological Association; editorial office address is University of Illinois, Urbana, Illinois. Journal is sent gratis to members of the Association; price to others is $7 per year.

112. *Radio Engineers, Proceedings of the Institute of*

Description: Periodical coverage is comprehensive for articles of interest to scientific workers in radio and allied subjects. Abstracts are semi-informative, without critical review and written by the staff of the Radio Research Organization of the Department of Scientific and Industrial Research, England. Books and government publications also are covered.

Magnitude (approx): 4000 abstracts per year; 250 journals covered.

Indexes: Annual author and subject, published by *Wireless Engineer* (See entry No. 140).

Publication information: Abstracts constitute a department in *Proceedings of the Institute of Radio Engineers*, published monthly by the Institute, 1 East 79th St., New York 21, New York. Price of the *Proceedings* is $18 per year; *Wireless Engineer*, published in London and carrying essentially the same abstracts, costs 32s per year. The annual index can be obtained from the latter journal for 2s 8d. An edition of the abstracts printed on one side of the page only is available to members of I.R.E. and to subscribers to the *Proceedings* at $15 a year.

113. *Radiofile*

Description: Is a subject indexing rather than an abstracting service. Periodical coverage is comprehensive for principal articles, as well as smaller "fillers," dealing with the technical aspects of radio, television, audio, and electronics. Entries are staff-prepared. Books, data collections, and other nonperiodical publications also are indexed.

Magnitude (approx): 1700 main entries per year; 20 journals.

Indexes: Each issue is in itself a cumulative index which includes everything appearing in previous issues for that year; thus the December number is an annual index.

Publication information: Radiofile is published bimonthly by Radiofile, 255 West 84th Street, New York 24, New York. Price is $1.50 per year or $2.25 for two years; annual index volumes are 35¢ for the 1946 issue and 50¢ each for 1947 and following.

114. *Radiology*

Description: Periodical coverage is relatively comprehensive for articles dealing with roentgenology and radiotherapy. Abstracts are informative and written by radiological experts.

Magnitude (approx): 1000 abstracts per year; 150 journals.

Indexes: Semiannual author and subject; a 20-year cumulative index covering 1923–42 and a 5-year cumulative covering 1943–47 also have been issued.

Publication information: Abstracts constitute a department ("Abstracts of Current Literature") in *Radiology*, published monthly by the Radiological Society of North America, 713 E. Genesee Street, Syracuse 2, New York. Price of journal is $8 per year; Canadian postage is $1 additional, other foreign postage $2.

115. *Railway Engineering Abstracts*

Description: Periodical coverage is selective for articles on all phases of the research and technology of railway engineering, on general engineering matters in which railway engineers have an interest, or on general science or broad new developments likely to influence progress in railway engineering. All types of abstract are employed. Abstracts are without critical review and are written by a panel of abstractors who are subject experts.

Magnitude (approx): 1200 abstracts per year; 40 journals, supplemented by abstract exchange with other services.

Indexes: Annual author and subject.

Publication information: Railway Engineering Abstracts is published monthly by the Institution of Civil Engineers, Great George Street, Westminister, London, S. W. 1, England. Gratis distribution is arranged with supporting institutions; Dominion and Colonial railway bodies may purchase the journal in bulk; price to individuals is 35s per year.

116. *Refrigeration Abstracts**

Description: Periodical coverage is selective of material of refrigeration interest in the general fields of natural sciences, engineering, engineering materials, foods, machinery and equipment, patents, refrigerants, refrigeration applications, and thermal insulating materials.

Magnitude (approx): Over 2000 abstracts per year.

Indexes: Subject—issued irregularly.

Publication information: Refrigeration Abstracts is published five times a year by The American Society of Refrigerating Engineers, 40 West 40th Street, New York 18, N. Y.; editorial office address is University of Tennessee, Knoxville, Tennessee. Price per year is $5 to members of the Society, $7 to domestic nonmembers, $8 to foreign subscribers.

117. *Refrigeration, Bulletin of the International Institute of*

Description: Periodical coverage is selective of articles dealing with the scientific and technical phases of research in the fields of refrigeration and low temperatures. Abstracts are informative, without critical review of the original and are prepared by authors and subject specialists on the staff. Books and government publications also are included.

Magnitude (approx): 800 abstracts per year; 120 journals.

Indexes: Annual.

Publication information: The Bulletin of the International Institute of Refrigeration is published in an English and in a French edition, each language on an alternating month, by the Institut International du Froid, 9 avenue Carnot, Paris 17, France. Subscription information should be obtained from the publishers.

118. *Revue Générale du Caoutchouc*

Description: Periodical coverage is selective for articles on rubber manufacture and rubber research. Abstracts are semi-informative, without critical review and written by professional staff abstractors. Books and selected patents also are covered.

Magnitude (approx): 1500 abstracts per year; 200 journals.

Indexes: None.

Publication information: Abstracts constitute a part of *Revue Générale du Caoutchouc*, published monthly by the Société des Editions Techniques Coloniales, 3 Square Petrarque, Paris XVI, France. Price per year of the *Revue* is 2500 fr., or of abstracts only 350 fr.

119. *Road Abstracts*

Description: Periodical coverage is comprehensive for articles of interest to road engineers or road research workers. Abstracts include all types, are without critical review and are written by professional abstractors on the staffs of the Road Research Laboratory and the Ministry of Transport. Books, government publications, transactions of conferences, and miscellaneous pamphlets also are covered.

Magnitude (approx): 800 abstracts per year; 150 journals.

Indexes: Annual author and subject.

Publication information: Road Abstracts is issued monthly in neostyled form to the technical press and in printed form as a supplement to the *Journal of the Institution of Municipal Engineers.* The neostyled edition is published by the Road Research Laboratory, D.S.I.R., Harmondsworth, West Drayton, Middlesex, England, and the printed edition by the Institution of Municipal Engineers, 84 Eccleston Square, London, S. W. 1, England. Individuals not members of the Institution may subscribe through it at a rate of 15s per year.

120. *Roentgenology and Radium Therapy, American Journal of*

Description: Periodical coverage is selective on basis of radiological interest. Abstracts are semi-informative, without critical review, and written by U. S. and Canadian radiologists. Occasional foreign papers also are covered.

Magnitude (approx): 800 abstracts per year; 150 foreign and U. S. journals.

Indexes: Individual index with each journal; no cumulative.

Publication information: Abstracts constitute a department in *American Journal of Roentgenology and Radium Therapy*, published monthly by Charles C. Thomas, Springfield, Illinois. Price of *Journal* per year is $10 to physicians; others may consult it in libraries.

121. *Rotol Digest*

Description: Periodical coverage is selective for articles pertinent to the firm's work on propellers and aircraft accessories. Abstracts are semi-informative, without critical review and written by the technical librarian.

Magnitude (approx): 2400 abstracts per year; 70 journals.

Indexes: None.

Publication information: Rotol Digest is published monthly or bimonthly by the technical library of Rotol, Ltd., Gloucester, England. Its distribution, other than that made within the company, is principally to libraries and scientific bodies. It is not offered for sale on a subscription basis; individuals interested in obtaining the *Digest* should write to the editor.

122. *Rubber Research and Summary of Current Literature, Journal of*

Description: Periodical coverage is comprehensive for articles on rubber science and technology, exclusive of those dealing wholly with the economic aspects of rubber. Abstracts are informative, usually without critical review, and written by professional abstractors. Books, patents, government publications, and miscellaneous pamphlets also are covered.

Magnitude (approx): 5000 abstracts per year; 200 journals.

Indexes: Annual author, subject, and patent.

Publication information: Abstracts constitute a department in the *Journal of Rubber Research and Summary of Current Literature,* published monthly by the Research

Association of British Rubber Manufacturers, 105 Lansdowne Road, Croydon, Surrey, England. Journal is sent gratis to Association members and to British government departments, and on an exchange basis to a limited number of other organizations. Price to individuals is £18 per year.

123. *Russian Accessions, Monthly List of**

Description: Publication consists of tables of contents of Russian journals grouped under major subject headings; no annotations or abstracts of individual papers are given. Sections of principal physics interest are Science and Technology. About one-third of the entries are translated into English.

Magnitude: An average of some 300 accessions are listed.

Indexes: None.

Publication information: The *Monthly List of Russian Accessions* is published by the Exchange and Gift Section, Library of Congress. It may be obtained at a price of $3 per year from the Superintendent of Documents, Washington 25, D. C.

124. *Russian Scientific Periodical Literature, Guide to*

Description: Periodical coverage is comprehensive for all Russian technical publications received by the Brookhaven laboratory. Entries are indicative, without critical review, and are translations of the authors' abstracts or his conclusions. Translations of original articles may be obtained on interlibrary loan. Complete translations are given in the *Guide* for important physics articles, particularly ones in nuclear physics.

Magnitude (approx): 400 abstracts and 6000 bibliographic entries per year; 30 journals.

Indexes: Index of periodical titles at the end of each volume.

Publication information: Guide to Russian Periodical Literature is published approximately every six weeks by Brookhaven National Laboratory, Information and Publications Division, Upton, Long Island, New York. It is sent gratis to AEC agencies and contractors; others may subscribe through the Technical Information Branch, U. S. AEC, P. O. Box "P," Oak Ridge, Tennessee. Information regarding price may be obtained from publisher.

125. *Seismology, Bibliography of*

Description: Publication lists comprehensively published articles which apply directly to the study of seismology or which are general studies of the interior of the earth; it is believed to be the only general listing of papers in this field. The few abstracts which are given are semi-informative and written by subject experts.

Magnitude (approx): 300 papers listed per year; 200 journals.

Indexes: Annual subject, decennial, and author.

Publication information: Bibliography of Seismology is published semiannually by Dominion Observatory, Department of Mines and Resources, Ottawa, Canada. It is distributed gratis to a limited list of agencies; information on such distribution should be obtained from the editor.

126. *Shipbuilding Research Association, Journal of the British*

Description: Periodical coverage is selective for articles of interest to shipbuilders, marine engineers, and ship owners. Abstracts are informative, without critical review and written by professional abstractors. Government publications, miscellaneous pamphlets, technically important trade literature, and some patents also are covered. Photostats of original papers are available to Association members.

Magnitude (approx): 900 abstracts per year; 220 journals.

Indexes: Annual author and subject.

Publication information: The *Journal of the British Shipbuilding Research Association* is published monthly by the Association, 5 Chesterfield Gardens, Curzon Street, London, W. 1, England. It is sent gratis to Association members and on exchange to selected other publications. Information regarding other distribution should be obtained from the editor.

127. *Spectrochimica Acta*

Description: Present coverage is comprehensive of European periodicals for articles in the field of spectrochemical analysis; plans are under way to make the scope world wide. Abstracts are informative and written by editors specializing in the fields treated. Books also are covered.

Magnitude: Number of abstracts per issue varies greatly.

Indexes: Author in each issue; author and subject in each volume.

Publication information: Abstracts constitute a department in *Spectrochimica Acta* published irregularly two or three times a year by Butterworth-Springer, Ltd., 227 Strand, London, W. C. 1, England. These abstracts are expected to supersede those formerly appearing as *Spectrochemical Abstracts*. Distribution is handled through Hilger and Watts, Ltd., 98 St. Pancras Way, London, N. W. 1, England.

128. *Squibb Abstract Bulletin*

Description: Periodical coverage is comprehensive of articles of interest to the company. Fields of physics interest are primarily general physical, inorganic and organic chemistry, and biophysics. Abstracts are informative, without critical review and usually staff-written although some author summaries are used.

Magnitude (approx): 5000 abstracts and 2500 title entries per year; 500 journals.

Indexes: Annual author.

Publication information: The *Squibb Abstract Bulletin* is published weekly by E. R. Squibb and Sons, 17 Columbia Heights, Brooklyn 2, New York. It is free to company employees and affiliates; price to libraries and individuals connected with educational institutions or hospitals is $10 per year. The *Bulletin* is not available to industrial concerns.

129. *State Publications, Monthly Checklist of*

Description: This bibliography and index is comprehensive of documents of the various States, excluding items likely to appear later in more permanent form and unimportant material of temporary interest such as announcement brochures, posters and the like. Entries occasionally carry annotations when necessary to clarify the contents of the item. This publication is probably the best single source for titles emanating from State university laboratories, engineering experiment stations, and so forth.

Magnitude (approx): 12,500 entries per year.

Indexes: Annual corporate author, personal author, subject and distinctive subject or title heading—all in one arrangement.

Publication information: The *Monthly Checklist of State Publications* is published by the Exchange and Gift Division, Library of Congress. It may be obtained from the Superintendent of Documents, Washington 25, D. C. at $1.50 per year.

130. *Technical Book Review Index*

Description: Index identifies book reviews in current scientific, technical and trade journals and quotes from them. To be listed, reviews must be English-language books of 25 pages or more, published during the current or preceding year and concerned with scientific or technical subjects. Reviewers' opinions and criticisms of books are included. Bound volumes of the periodicals in which the reviews appear are catalogued and shelved for reference use in the Technology Department, Carnegie Library of Pittsburgh.

Magnitude (approx): 1600 reviews per year; 850–900 journals.

Indexes: Annual author with December issue of Index.

Publication information: Technical Book Review Index is published monthly (except July and August) by Special Libraries Association, 31 East Tenth Street, New York 3, New York. Price per year is $7.50 in the U. S., $8 elsewhere.

131. *Technical Data Digest*

Description: Periodical coverage is selective for articles of aeronautical interest. Abstracts are indicative, without critical review, and written by professional abstractors except where author abstracts are used. Books and miscellaneous government and other pamphlets also are covered. Agencies receiving the *Digest* may borrow original articles.

Magnitude (approx): 4000 abstracts per year; 1000 journals.

Indexes: Semiannual author, title, and source.

Publication information: Technical Data Digest is published monthly by Central Air Documents Office, Wright-Patterson Air Force Base, Attention CADO-T, Dayton, Ohio. It is not offered for sale on a subscription basis but is distributed gratis automatically to numerous government and other agencies; information regarding such distribution should be obtained from the issuing office.

132. *Technical Information Pilot*

Description: Coverage is comprehensive for technical reports on government-sponsored research received by the Navy Research Section of Library of Congress; no conventional periodicals are included. Abstracts are about 10 per cent indicative, 10 per cent semi-informative and 80 per cent informative; they are written by professional abstractors with scientific training and include no critical review of the original. Catalog cards (3 × 5 in.), made up in broad subject classifications, are sent out on limited distribution. Loan copies, photostats, and microfilms of original reports are available to approved addressees.

Magnitude (approx): 6000 abstracts per year of documents not carrying military security classification.

Indexes: Quarterly subject with every fourth one being an annual cumulative.

Publication information: The unclassified *Technical Information Pilot* is published an average of seven times per month by the Navy Research Section, Science Division, Library of Congress, Washington 25, D. C. It is sent gratis to addressees approved by the ONR; application for such distribution should be made through ONR. The *Pilot* is not offered for sale on a subscription basis.

133. *Technical Reports, Bibliography of*

Description: Publication lists unclassified technical reports received from civil and military agencies of the United States and from cooperating foreign governments. Subject fields include aerodynamics, atomic and nuclear physics, chemistry and chemical applications, electrical engineering, electronics, general physics, medical physics, metals and metallurgy, photography, plastics, textiles and others. Abstracts are indicative to semi-informative in type. Each entry indicates whether the document is obtainable in printed, mimeograph, microfilm or photostat form and the price. Beginning July 1, 1950, Office of Technical Services also assumes responsibility for public notification and distribution of unclassified AEC reports.

Magnitude (approx): 4000 documents listed per year.

Indexes: Annual author and subject.

Publication information: Bibliography of Technical Reports is published monthly by the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. Price per year is $5.

134. *Telecommunications, Annales des**

Description: Periodical coverage is comprehensive for articles on the scientific and technical aspects of telecommunications and closely related research. Abstracts are indicative.

Magnitude (approx): 5000 abstracts per year.

Indexes: No information.

Publication information: Annales des Telecommunications is published monthly by the Service de Documentation Interministérielle du Centre National d'Etude des Telecommunications (C.N.E.T.), 24 rue Morere, Paris 14, France. Price per year is 3500 fr.

135. *Telescoping the Technical News*

Description: Periodical coverage is comprehensive for articles on glass research and related fields. Abstracts are semi-informative, without critical review, and written by professional abstractors on the staff. Patents also are covered.

Magnitude (approx): 2000 abstracts per year; 75 journals.

Indexes: None.

Publication information: Telescoping the Technical News is published approximately biweekly by the Glass Division Research Library, Pittsburgh Plate Glass Company, Creighton, Pennsylvania. Journal is not offered for sale on a subscription basis; information regarding gratis distribution should be obtained from library of publishing agency.

136. *Textile Institute, Journal of the**

Description: Periodical coverage is comprehensive for papers on fibers and their production, yarns and fabrics, pertinent chemical processes, building and engineering. Patents also are covered.

Magnitude (approx): 3000 abstracts per year.

Indexes: Annual.

Publication information: Abstracts constitute a department in the *Journal of the Textile Institute,* published monthly by the Institute, 16 St. Mary's Parsonage, Manchester, England. Price per year to Institute members is £2 2s, to nonmembers £3 10s.

137. *Textile Research Journal*

Description: Periodical coverage is selective for articles on fundamental or applied research pertinent to the textile industry, and on industrial engineering and economics bearing on textiles. Abstracts vary from indicative to informative with a preponderance of the latter; they are without critical review and are written variously by paid abstractors, members of the Textile Research Institute, and authors of the articles. Books, government publications and miscellaneous pamphlets also are covered.

Magnitude (approx): 1000 abstracts per year; 135 journals.

Indexes: Annual author and subject, included with annual index of journal.

Publication information: Abstracts and book reviews constitute departments in the *Textile Research Journal* published monthly by the Textile Research Institute, 10 East 40th St., New York 15, N. Y. Journal is sent gratis to Institute members; price per year to others is $15 to individuals, $10 to public and institutional libraries. Abstract and book review sections were to be available for separate purchase beginning in January, 1950; price should be obtained from the Institute.

138. *Verres et Réfractaires*

Description: Periodical coverage is selective for articles on glass technology and on the refractories used in the glass industry. Abstracts are semi-informative, without critical review and written by professional staff abstractors. Books, patents, government publications, and miscellaneous pamphlets also are covered.

Magnitude (approx): 450 abstracts per year; 80 journals.

Indexes: None.

Publication information: Abstracts constitute a department ("Analyses des Articles de Revue") in *Verres et Réfractaires*, published bimonthly by the Société d'Editions Verrières et Céramiques, 34 rue Michel-Ange, Paris 16, France. The journal is sent gratis to members of the Institut du Verre and to some universities; price to others is $10 per year.

139. *Water and Water Engineering*

Description: Periodical coverage is selective for articles having direct application to waterworks and water supply engineering including all forms of water treatment, laboratory control, and corrosion control. Abstracts are written partly by professional abstractors and partly by practising experts in the field.

Magnitude (approx): 70 abstracts per year; 55 journals.

Indexes: Annual subject.

Publication information: Abstracts constitute a department ("Monthly Review of Current Literature") in *Water and Water Engineering* published monthly by The Colliery Guardian Company, Ltd., 30–31 Furnival Street, Holburn, London, E. C. 4, England. Price of journal is 15s per year.

140. *Wireless Engineer*

Description: Periodical coverage is selective on the basis of interest to the radio physicist or engineer; priority is given to new work and to papers of general radio engineering interest. Abstracts are semi-informative, without critical review and written partly by professional abstractors and partly by subject experts. Only a few publications other than periodicals are covered.

Magnitude (approx): 3500 abstracts per year; 200 journals.

Indexes: Annual author and subject.

Publication information: Abstracts constitute a department in *Wireless Engineer*, published monthly by Illiffe and Sons, Ltd., Dorset House, Stamford Street, London, S. E., 1, England. The abstracts are included by arrangement with the Department of Scientific and Industrial Research. Price of journal, both in Great Britain and abroad, is 32s per year; a six-months subscription can be entered at 16s (see also Entry No. 112 for *Proceedings of the I.R.E.*).

141. *World Medicine, Abstracts of*

Description: Periodical coverage is selective for articles containing recent medical advances or their confirmation and comprehensive review. Abstracts are informative, may contain bracketed criticism by the abstractor, and are written by subject experts. Government publications and other miscellaneous nonperiodical literature also are covered. Featured are sections on tracer elements, and diagnostic and therapeutic radiology. Photocopies of original articles are obtainable.

Magnitude (approx): 5500 abstracts per year; 2200 journals.

Indexes: Monthly and semiannual author and subject.

Publication information: Abstracts of World Medicine is published monthly by the British Medical Association, B.M.A. House, Tavistock Square, London, W. C. 1, England. Price per year is £3 3s, in Great Britain, $13 in the United States.

142. *X-Ray and Electron Diffraction Papers, Classified Bibliography of*

Description: Is a listing rather than an abstracting service. Periodical coverage is comprehensive; articles are listed if they concern the use of x-ray or electron diffraction, or the production of x-ray or electron beams or equipment. Book reviews also are listed.

Magnitude (approx): 900 papers listed per year; 130 journals.

Indexes: None.

Publication information: Classified Bibliography of X-Ray and Electron Diffraction Papers is published twice a year by the American Society for X-Ray and Electron Diffraction, Bell Telephone Laboratories, Murray Hill, New Jersey. It is sent gratis to Society members; nonmembers may obtain it from the Society secretary at $1 per copy.

143. *Zinc Development Association Abstracts*

Description: Periodical coverage is comprehensive for articles pertaining to the fabrication and use of zinc, zinc compounds, and related materials. Abstracts are mostly semi-informative although matters of relatively minor interest are treated indicatively. Critical review is given only in the case of books; all abstracts are written by scientifically trained staff members. All applicable nonperiodic publications, including patents, also are covered.

Magnitude (approx): 1000 abstracts per year; 150 journals are covered and much additional material is used which has been seen in abstract form only.

Indexes: Annual author and subject.

Publication information: Zinc Development Association Abstracts is published monthly by the Association, Lincoln House, Turl Street, Oxford, England. It is sent gratis to the Association and its affiliates and to other interested individuals whose request has been approved by the publisher.

144. *Air University Periodical Index**

Description: Journal is a quarterly subject guide to important articles appearing in 23 military, scientific, and technical periodicals not included in the commercial index services received by its issuing organization.

Magnitude: Between 800 and 900 entries in Volume 1, No. 1 for October–December 1949.

Indexes: Service itself is a subject index.

Publication Information: The *Index* is to be issued quarterly by Air University Library, Maxwell Air Force Base, Alabama. Information regarding distribution should be obtained from the issuing agency.

145. *Meteorologische Rundschau*

Description: Periodical coverage is comprehensive of articles of meteorological interest. Abstracts are indicative, include no critical review of the original and are written by authors or other subject experts. Journal carries abstracts under heading "Referate" and a title listing under "Neuerscheinungen." Other publications, including books, government publications and miscellaneous pamphlets, which come to the editor's attention, also are covered.

Magnitude (approx.): 1500 abstracts per year; 100 journals.

Indexes: Annual author and subject.

Publication Information: Meteorologische Rundschau is published monthly by Springer-Verlag, Berlin-Charlottenburg, Jebenstrasse 1, Germany. Information regarding subscription price is not available at this writing.

Index to Services

The task of indexing satisfactorily the services listed above is complicated by the great variation in breadth of subject coverage existing among them. Some confine their interest to a single, limited segment of physics, chemistry, or one of the engineering fields while others cover one or more major subject areas comprehensively. Consequently, if a subject-heading breakdown sufficiently detailed to give adequate information about the services of limited scope were extended in the same detail over the topics treated in the more comprehensive services, the resulting over-all index would be very long, approximating a composite of all the journals' annual indexes. The somewhat unorthodox compromise adopted here is intended to provide the physicist and technical librarian with a reasonably adequate reference tool which is not also excessively cumbersome; its basic pattern is as follows:

1. Specialty and semispecialty services, like *Coil Spring Journal* and *Gas Abstracts*, are shown under detailed subject headings descriptive of their limited subject coverage;
2. Services of relatively broad coverage, like *Physics Abstracts* and *Chemical Abstracts*, are shown principally under one or more general headings such as Chemistry (general coverage) or Physics (general coverage). Then they also are indexed under the appropriate more detailed headings which already are in the index because of the first rule.

The index also shows exact titles of all services, journals, organizations, and publishers whose names appear in the entries. Index figures refer to the list sequence numbers of the abstracting and indexing services.

Architectural Physics

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MANY times we have heard that a student forgets the contents of a course just as soon as he completes it. Because this contains a certain element of truth, a new course has been inaugurated at the University of Oregon for seniors majoring in architecture. These students have completed the usual required work in college physics, but on reaching their fifth year in architecture they are presented with many problems in architectural design dealing with plumbing, heating, illumination, and acoustics. A real understanding of these applied subjects requires the use of many basic principles of physics which need to be recalled to the students' attention.

This new course in architectural physics is given concurrently with "Construction VI" which deals with the mechanical accessories to buildings: plumbing, heating, ventilating, electric lighting, and acoustics. It contains the basic physical principles required for an adequate understanding of these subjects at a time when the students have a better appreciation of their value. As an illustration, if their studies of heating include the heat pump, the work in architectural physics would cover the laws of thermodynamics, Carnot and Rankine cycles, entropy, efficiency of heat engines and coefficient of performance with adequate explanation of reversible and irreversible cycles. This combines a review of college physics with an introduction to new material not usually covered in the first year course, for one would hardly find Rankine cycles or entropy in the usual college course, especially with applications to fluids other than ideal gases.

TABLE I. Material covered in course.

Concurrent study—Plumbing
Physics of Liquids—(6 lectures)
Concurrent Study—Heating
Heat and Thermodynamics—(4 lectures)
Radiation—(1 lecture)
Structure of the Atom—(1 lecture)
Concurrent Study—Illumination
Spectroscopy and Nuclear Physics—(2 lectures)
Electricity—(6 lectures)
Optics, Illumination, and Color—(10 lectures)
Concurrent Study—Acoustics
Sound—(2 lectures).

The selection of the teaching staff for a course in architectural physics is a real problem, in that a teacher must be well grounded in fundamental physics and in addition must have an appreciative understanding of the practical problems of architecture. A general discussion of a particular subject is not adequate; a detailed presentation of the actual physical principles involved in the problem at hand is essential. A short review of the material covered in the lectures (Table I) illustrates the importance of this correlation between theory and practice.

Let us take as an example of this relationship the case of electric wiring. Here the material required as a background is extensive. We deem it wise to cover Ohm's law, d.c. and a.c. circuits, series and parallel connections, conductors and insulators, Joule's law, and temperature coefficient of resistance. Typical practical problems would deal with the requirements of the National Electrical Code as to wire size, inclusion of more than one wire in one conduit, fusing, and insulation.

The lectures are supplemented with slides and a reasonable number of lecture demonstrations, usually different from those used in general physics, although the same demonstration is used if it is pertinent to the subject under discussion.

Details of derivations are generally omitted, but basic algebraic relations are carefully set up and solutions are given without the usual mathematical details. Care is taken to point out the importance of the various factors in the solution. For example, the differential equation for an a.c. series circuit is built up from its component parts; then without the usual mathematical operations, the solution is given, with emphasis on reactance, impedance and the similarity to Ohm's law for d.c. circuits.

At the present time no one adequate textbook is available for the entire field. This is a blessing in disguise because the student must use a set of reference books. He obtains a broader understanding of the subject and experience in library work. He must possess a copy of any good

TABLE II. References used by students.

A standard college physics textbook.
Babbitt, *Plumbing* (McGraw-Hill, 1928).
Cook, *Electric Wiring* (Wiley, ed. 3, 1933).
Cook, *Elements of Electrical Engineering* (Wiley, ed. 3, 1935).
Cork, *Heat* (Wiley, ed. 2, 1942).
Ebaugh, *Engineering Thermodynamics* (Van Nostrand, 1940).
Evans, *Color* (Wiley, 1948).
Gay and Fawcett, *Mechanical and Electrical Equipment for Buildings* (Wiley, 1949).
Kraehenbuehl, *Electrical Illumination* (Wiley, 1942).
Knudsen and Harris, *Acoustical Designing* (Wiley, 1950).
Moon and Spencer, *Lighting Design* (Addison-Wesley, 1948).
National Electrical Code (National Fire Protection Ass'n., 1947).
Olson, *Elements of Acoustical Engineering* (Van Nostrand, 1940).
Richardson, *Acoustics for Architects* (Arnold, 1945).
Richtmyer and Kennard, *Introduction to Modern Physics* (McGraw-Hill, ed. 3, 1947).
Severns and Fellows, *Heating, Ventilating and Air Conditioning Fundamentals* (Wiley, ed. 2, 1949).
Sporn, Ambrose and Baumeister, *Heat Pumps* (Wiley, 1947).
Watson, *Acoustics of Building* (Wiley, ed. 3, 1941).
Worthing and Halliday, *Heat* (Wiley, 1948).
Zeleny, *Elements of Electricity* (McGraw-Hill, ed. 2, 1935).

college textbook on physics, plus a copy of Evans' *Color* which we have found to be an excellent reference for this subject. A list of other references used is given in Table II.

Grades are based upon the results of examinations given once at the end of each term. An examination is based primarily on applications of physics to various problems in architecture, rather than on the basic principles themselves. At the end of the third term a report is required on a detailed study of the physical laws that are needed to solve some practical architectural problem, such as heating a room with radiant heat panels.

The course in architectural physics is covered in thirty-two lectures, given once each week for the school year. A summary of the work now being covered in each period is given in Table I.

This list of subjects appears formidable and it hardly appears possible that it can be covered in thirty-two lectures; but it must be remembered that a majority of the subjects were covered in the basic college course and only a review is required. A large proportion of the lecture time is given to the extension of the original background physics, and to the inclusion of new subjects, such as Reynold's numbers, which are required to bring out essential factors in architectural applications.

Our experience over the past ten years has given support to the idea that a course such as this can be of value. We find that it supplements the student's knowledge and reorients him in the ways of analytical physical methods.

1950 Summer Program on "Science in General Education" at Harvard University

The Harvard Summer School will offer a program in "Science in General Education" during the 1950 Summer School. This program will be an expansion of the experiment initiated during the summer of 1949.

The program is designed for all those who teach science to nonscientists. It will open on July 10 with an intensive Workshop under the general direction of PROFESSORS I. BERNARD COHEN and FLETCHER WATSON of Harvard. This Workshop will last four days and will provide an opportunity for teachers from colleges, junior colleges, and secondary schools (and graduate students who are prospective teachers) to examine the methods, aims, and practices applied in the introductory courses in science in the Harvard General Education program.

During the Workshop there will be ample opportunity for consultations between students and panel members about practical problems involved in teaching science courses. There will be afternoon sessions at which prepared papers will be presented. These papers will deal with such problems as "The Historical Approach and the Use of Historical Documents"; "The Value of Considering Science as an Organized Social Activity"; "The Role of Science in Technology and as a Factor in Social Change"; "The Need for a Viewpoint on the Philosophy of Science"; "Special Problems in the Biological Sciences"; "Aims and Objectives, and Methods of Testing Them." Among the experts who will present the papers will be PROFESSORS PHILIPPE LE CORBEILLER, EDWIN C. KEMBLE, and EDWARD S. CASTLE.

Those able to give more intensive consideration to the General Education approach to the teaching of science will be able to enroll in a special course, also under the direction of PROFESSORS COHEN and WATSON, which will begin July 5, include the Workshop, and continue until August 12. It will provide substantive data for use in the teaching of science and will consist of an introduction to the use of historical case materials in the study of science, a general survey of teaching methods in the sciences, an evaluation and testing of objectives, and the methods of organizing and conducting science courses.

In addition to this special course, those enrolled in the

(*Continued on page 342*)

Slugging Out a Case for the Pounders

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INCREASING portions of applied mechanics literature are being written in terms of the slug as the unit of mass. Writers, both teachers and practicing engineers, during the past ten years have commented pro and con on this practice. Some[1] advocate the pound as the unit of mass for good, practical reasons. Others[2] advocate the slug or $m=w/g$ as the unit of mass, following the pattern set by some professional writers; the NACA has for the past ten years been using the slug in their definitions and tables for aerodynamics. Still others[3] suggest various substitutes, such as new length units, new symbols, or new names for old concepts.

The above divergence of opinion is reflected in the teaching of mechanics, which, as most of us realize, is not uniform. Sometimes mass is treated as a "derived" concept, and at other times as a "fundamental" one. Some teachers and texts employ the slug, others the pound, and others refuse to name the mass unit, calling it w/g or lb sec^2/ft. Out of this medley there are discernible two schools of thought, "Pounders" and "Sluggers."

It is the purpose of this paper (a) to demonstrate that the pound is the unit of mass employed in actual practice, (b) to describe the practical gravitational system now employing this unit, and (c) to show that this system works out easily and conveniently in teaching as well as in practice. The remarks made here refer specifically to the English gravitational system, but are applicable to any such system, including the metric gravitational system.

The absolute systems also have a proper place in physics and engineering, and will always be useful in certain situations. There is no intention of discussing in this paper whether or how they should be taught. Because most people never have occasion to use them, however, it might be more efficient to teach the gravitational systems as the basic ones, reserving the absolute systems for physicists and engineers.

"Mass" Psychology

The lay mind in English-speaking countries has for the past two centuries been committed to the pound as the unit of mass and as the unit of force; the same may be said about the gram in countries where the metric system is in vogue.

Those pioneers who set up the gravitational system deliberately chose the pound as the unit of both mass and force. The convenience of the pound as the standard unit of mass made it unnecessary to introduce the slug. As an example of this convenience consider that the nourishment in food is proportional to its mass, say 5 lb of sugar; its weight, also 5 lb, only makes it arduous to carry it up the back steps. But once in the kitchen you can easily determine whether you received honest "weight" (mass) by weighing it. If the scales show 5 lb you know at once that you have a 5-lb mass of sugar, without having to divide by 32.2 to obtain 5/32.2 of a slug. The pound as a unit of both force and mass is convenient and was chosen to enjoy just this operational convenience. It is foolhardy and inefficient to alter this convention.

In thinking about mass we intuitively think first about so much matter; it is one of the first ideas we learn in childhood. The perception of the inertial properties of matter is also made at an early age. We soon learn to estimate mass by its weight and other inertial properties, but we still think about mass as so much matter. To a layman 5 lb of sugar is just so much sugar, and not the coefficient of the acceleration produced when a given force acts upon it, even though he may erroneously call the amount its "weight."

There are instances in common usage where the word "weight" is wrongly employed. It is sometimes used where "mass" is meant. Those

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[1] Fassler, *Am. J. Physics* **15**, 361D (1947); Hawkins and Moss, "Alice and the Sluggers," *Ibid.* **13**, 409–11 (1945); Ross, *Ibid.* **13**, 121 (1945); Sleator, *Ibid.* **8**, 134 (1940); **15**, 251–4 (1947).

[2] Binder, "The Case for the Sluggers," *J. Eng. Ed.* **39**, 599–600 (1949); Hagenow, *Am. J. Physics* **14**, 401–2 (1946); *Nat'l. Adv. Council for Aeronautics*, 25th, 26th, 27th, Annual Repts., 1939–1941; Winans, *Am. J. Physics* **12**, 239D (1944).

[3] O'Leary, *Am. J. Physics* **15**, 146–53 (1947); Schuchard, *Ibid.* **10**, 58D (1942); Varney, *Ibid.* **15**, 514–5 (1947); Wadlund, *Ibid.* **9**, 189–90 (1941).

objects used for weighing are called "weights" but are actually replicas of the standard masses, either English or metric. In the restricted physical meaning of the word, one cannot handle weights as objects; one can handle only masses. This identification of an entity with one of its attributes is so natural that the writer ventures to predict that if the slug were ever to be accepted by the trade as the unit of mass (whether "fundamental" or "derived") we would soon see scales marked in slugs, and would hear people saying that things weigh so many slugs! There is no avoiding this quirk of human nature, viz., to use the same unit for mass as for weight.

The universal recognition of the pound as the unit of mass is everywhere evident. Handbooks, whether physical, chemical, mechanical, thermal, or electrical, list the physical properties in terms of the pound, not the slug, as the unit of mass. Where the metric system is employed the mass unit is the gram, and not the metric slug. It is obviously impossible to recalculate all our handbooks, and it is unnecessary. Textbooks purporting to use the slug invariably state their problems in terms of pounds, and slugs appear only in the answers. The mass unit employed in trade transactions everywhere is the pound or ton, never the slug. Nowhere outside of textbooks and theoretical papers does one see the slug.

Another psychological peculiarity about the human mind is its weakness for names—in order to be able to think about a concept it must have a name for it. For this reason it is easier for the student to learn kinetics if he has a name for the unit of mass being used in equations. Many textbooks and teachers avoid giving a name to the mass concept and use only w/g or lb sec^2/ft to represent mass. This deprives the student of a very necessary handle with which to manipulate the mass concept. We must have a name and a unit for the mass concept, and pound is the most familiar one, so why not use it?

The Remedy

The disinclination to employ the pound as the unit of mass in mechanics may arise either from an insistence upon making the constant of proportionality equal to unity, or from a narrow interpretation of the second law. Newton did not say that "Force is equal to mass times acceleration"; he only said they had to be proportional. It is therefore quite proper to derive the force equation in the usual way, as follows:

$$F_1/a_1 = F_2/a_2 \cdots = w/g = Km, \tag{1}$$

where we may choose K to fit convenient units, instead of choosing units to give K an arbitrary value.[4] Now, if we want mass and weight to have the same units, so that $m=w$, we must take $K=1/g$. Then

$$\mathbf{F} = m\mathbf{a}/g \quad \mathbf{w} = m\mathbf{g}/g \quad \text{and} \quad w=m \tag{2}$$

are the equations relating force, weight, and mass in the gravitational systems. This is the remedy for the existing confusion. In the above equation the factor g is a scalar representing 32.2 ft/sec^2 or 980 cm/sec^2, depending on whether the English or metric units are being used. The systems employing equal mass and force units might well be called "practical" gravitational systems, to disinguish them from the impractical and unused systems where slugs are employed as mass units.

Inherent in this proposal is the adoption of a set of four dimensions, MFLT, instead of three independent ones, FLT or MLT. Mathematically and logically it is unnecessary to employ four dimensions, but pedagogically the mass dimension is indispensable, as intimated above. Of course, in energy equations mass must be expressed in terms of force and the other dimensions, as it is now. But no matter how logically rigorous the demonstration that we can choose force as the fundamental unit, and derive from it a mass unit (e.g., slug), mass is still the fundamental concept, and it is simpler to keep it. Furthermore, it is of great practical convenience in any system, because mass and force always play complementary roles.[5]

[4] In this paper we employ the conventional notation for scalars and vectors. Boldface type represents vectors and italics represents scalars and scalar magnitudes of vectors. In Eq. (1) we mean the magnitudes of $\mathbf{F}$, $\mathbf{a}$, $\mathbf{w}$, $\mathbf{g}$. This usage of symbols should remove the very reasonable objection to the division of two vectors, $\mathbf{w}/\mathbf{g}$, provided it is explained to students that the scalar magnitudes and not the vectors are to be divided in Eq. (1). Thus, g means the scalar magnitude of the vector $\mathbf{g}$, and has the dimensions L/T^2. To complete the collection of symbols we may write $\mathbf{g}_1$ as the unit vector of the acceleration of gravity. Then $\mathbf{g} = g\mathbf{g}_1$ and $\mathbf{w} = m\mathbf{g}_1$.

[5] The more fundamental position of mass contrasted with force is illustrated in the absolute systems where pound and gram are the layman's units of mass. Students and laymen seem to accept fairly readily the poundal and the dyne as derived units of force.

Mass Concepts and Force Concepts

The concepts encountered in kinetics may be separated roughly into several categories, one of which might be labeled "mass," and another "force." For example, moment of inertia and momentum may be considered as mass concepts because they involve mass explicitly in their definitions. On the other hand, such concepts as torque and impulse might be regarded as force concepts because force occurs explicitly in their definitions. And for each mass concept there is usually a corresponding force concept, e.g., moment of inertia and torque, moment and impulse. These concepts thus occur in pairs, and it preserves the balance or symmetry of this natural classification to employ mass and force as separate intuitive concepts than to employ force alone, which requires that mass be replaced by an involved combination of symbols. Whether pound shall mean force or mass depends upon the concept we are dealing with.

The advantage of using the four dimensions MFLT is demonstrated in the following examples, which yield for the mass concepts dimensions that are consistent with their definitions. For impulse and momentum the equation is

$$\mathbf{F}t = m\mathbf{v}/g,$$

where impulse is in lb sec, a force concept, and momentum ($m\mathbf{v}$) is in lb ft/sec, consistent with its definition of "mass times velocity." In rotational kinetics

$$\mathbf{T} = \mathbf{r}\times\mathbf{F} = \boldsymbol{\alpha} I/g,$$

where torque $\mathbf{T}$ is in lb ft and I, moment of inertia, is in lb ft^2, consistent with the definition $I = \Sigma mr^2$, or mass times the square of a length. The lb in torque means force, and the lb in moment of inertia means mass.

In the above examples of mass and force concepts the question whether lb shall mean force or mass is revealed by the context. We know which it shall be by the nature of the concept we are considering. There need be no ambiguity about the answer to this question; academic and practical problems never ask us to identify without a context an arbitrary combination of units. The important thing is to know and specify what kind of concept we are talking about, then the units will have a definite meaning. The recognition of which units to associate with which concepts must become second nature, preferably without additional unnecessary symbols. This will be most readily accomplished by the students if they are taught in terms of the familiar pound as mass and as force.

This proposal, by including mass as a basic dimension along with force, preserves mass concepts in terms of their fundamental definitions. When the FLT system is universally applied, the mass concepts lose their identity and acquire such unrecognizable forms as lb ft sec^2 for moment of inertia, and lb sec^2/ft^4 for density. Keeping mass as a basic dimension thus serves two purposes: It preserves the complementary roles of mass and force, and also maintains the mass concepts in forms recognizable from their definitions.

Other Applications

The practical value of the proposed equation is demonstrated when applied to other situations. For instance, kinetic energy derived in the usual way

$$E_k = \int \mathbf{F}\cdot d\mathbf{s} = (m/g)\int \mathbf{a}\cdot d\mathbf{s}$$

$$= (m/g)\int (d\mathbf{v}/dt)\cdot d\mathbf{s} = mv^2/2g$$

shows explicitly that mass must be divided by g to produce the proper value for energy in the practical gravitational systems.

Bernoulli's equation in hydrodynamics has the three terms: wh for potential energy, $mv^2/2g$ for kinetic energy, and pm/ρ for "pressure energy." In the last term m and ρ contain the same mass unit (lb), and the term thus has the dimensions of energy. The equation in the proposed form thus becomes

$$wh + mv^2/2g + pm/\rho = c_1.$$

When this is divided by the mass m we obtain

$$h + v^2/2g + p/\rho = c_2,$$

remembering that $w/m = 1$.

In the above, and in all other equations involving mass and force, g appears in exactly those places where we now have to use it (if we

don't forget to put it in). And in Bernoulli's equation the last term has no g because ρ is in pounds and not in slugs. In the slug system this last term reads $p/\rho g$, and to calculate it we must divide ρ (in lb/ft^3 from the tables) by 32.2 to convert it into slugs/ft^3, then turn right around and multiply it by 32.2 to accord with the formula—a useless "run-around" that the better students justly ridicule. Inasmuch as the vast majority of people use almost exclusively the practical gravitational system, with the pound as unit of mass, it seems only sensible to teach them the equations employing this unit rather than those employing the slug. Furthermore, the equations using the pound put the g exactly in those places where we now have to remember putting it.[6]

A further advantage in using the pound as the mass unit in the gravitational system is that in the absolute system the mass concepts have the same dimensions and numerical values; for instance, moment of inertia is the same in both systems.

Teaching What We Practice

This writer has taught the above-mentioned version of the force equation, and it works admirably well. The students see where to divide or multiply by g, and they have only to enter the mass or weight number in the proper place. This procedure eliminates the lack of confidence usually encountered at this point in teaching mechanics. Students successfully follow this instruction with very few errors that can arise by the misuse of g.

Because the pound is the established unit of mass and force we are compelled to introduce somewhere in our calculations the factor g, either explicitly in the force equation, or implicitly in converting pounds to slugs. It is just as impossible to keep g out of mechanics as it was for Oliver Heaviside to keep 4π out of electromagnetics.

Summary

The confusion in the teaching of mechanics, judging by the considerable bibliography on the subject, is apparently owing to a disinclination to employ the pound (or gram) as the unit of mass and of force in the equations for the gravitational systems. Two proposals are made: (1) that the pound (or gram) be employed as the unit for both mass and force in the equations for the gravitational systems, and (2) that we use the four dimensions MFLT. The force equation becomes—

$$\mathbf{F} = m\mathbf{a}/g \quad \text{and} \quad w = m,$$

where m is the scalar magnitude of the weight vector $\mathbf{w}$. The applications of the proposed scheme to kinetics and in Bernoulli's equation are shown as examples. With this choice of units the factor g appears in all equations at those places where we now have to remember to put it. The proposed remedy employs only long-established units; new symbols and units are not needed.

In restating this case for the "Pounders" the writer is fully aware that slugs would make some equations more convenient to handle; but for two centuries people, including teachers and engineers, have stubbornly insisted on using in their daily lives the same unit for mass and for force. This everyday usage has survived because it is convenient and efficient; it demonstrates the wish and convenience of the majority. The proposal described here puts the equations of mechanics into a form where the practical mass unit (pound or gram) has a natural place. It is therefore recommended that everyone adopt the pound (or gram) as the standard unit of mass and of force in theory as well as in practice. This would not only simplify a knotty teaching problem, but would also increase the efficiency of our entire technology.

Acknowledgments

The writer wishes to thank Professor Paul O. Hoffmann for his stimulating comments on reading the manuscript; and he also wishes to acknowledge his indebtedness to the several colleagues with whom he has discussed this problem, especially to Dr. K. L. Hertel for his apt examples of the distinction between mass and weight, and to Dr. C. V. Bertsch for emphasising the proper handling of vectors in deriving the force equation.

[6] Hawkins and Moss (reference 1) previously suggested this kind of treatment, but did not demonstrate its applications, as has been done here.

Use of WWV Signals to Time Pendulums

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THE measurement of the period of a pendulum by comparing it with a standard pendulum by the method of coincidences enables the student to determine the acceleration due to gravity with great accuracy, especially when a Kater's pendulum is used. The simple theory and the high accuracy of this method are its main advantages. A further advantage which greatly interests students, when their attention is called to it, is the similarity which exists between this method and the method of beats which is used frequently in acoustics. The theory and equations for the two methods are identical.

While the standard pendulum-clock in this laboratory was being repaired, it occurred to us that the period of a pendulum might be determined with the method of coincidences by comparison with the pulses which are broadcast on several carrier frequencies by the Central Radio Propagation Laboratory of the National Bureau of Standards. These pulses are transmitted accurately at intervals of one second and it seemed that they might be useful during the time that radio reception was dependably good. The results have been unexpectedly good and the experiment has yielded satisfactory and interesting results.

It is not suggested that an experiment of this type is suitable for the elementary laboratory. For beginning students the direct comparison of two pendulums is preferable because of the simplicity of concept. Advanced students, however, will find the use of the present method an interesting and accurate variation of the usual procedure. The equipment needed is very inexpensive.

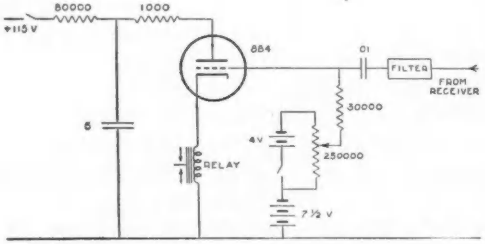

Fig. 1. Circuit for control of mechanical relay. Resistances are given in ohms, capacitances in mfd.

A Wilcox Type F_3 radio receiver, tuned to 5 Mc/sec, was used. This is a crystal-controlled superheterodyne which has been available on the surplus market at a price less than twenty dollars. This inexpensive receiver has been found to be superior to a high grade communications receiver because the latter has to be occasionally retuned during the course of an experiment. A half-wave antenna with a total length of about 90 ft is used. Connection is made to the center of this antenna with a long twisted-pair line. The output from the receiver is first sent through a United Transformer Co., Type FL-8-A 1000-cycle filter[1] and then to the grid of the thyratron circuit shown in Fig. 1. This circuit is a saw-tooth oscillator whose grid bias is adjusted until oscillations do not occur with no signal going into the grid. A pulse from the receiver causes the thyratron to fire and hence the relay in the cathode circuit is closed accurately at intervals of one second. The contacts of this relay, a 20-ohm telegraph relay, are connected in series with a sounder, dry cells and the pendulum. A "coincidence" is indicated by a short series of clicks of the sounder. Heater and plate voltages for the circuit are obtained from the receiver.

The filter is an important item in this circuit. Since each pulse consists of 5 cycles of a 1000 cycles/sec oscillation, the presence of this filter improves the signal-to-noise ratio greatly.

The performance of this circuit is excellent most of the time during all seasons and during all times of the day. Extremely adverse atmospheric conditions or violent and persistent local electrical disturbances will prohibit its operation. Most of the measurements were made with a Kater's pendulum whose half-period, on the one knife-edge used, is 1.003274 sec for an amplitude of 0.0100 rad (1.00 cm). The coincidences, which occur at about 5 min intervals, were timed with an electric clock of the "kitchen" type. The error due to timing, when observations are made for

[1] Filters of this type and crystals for the Wilcox receiver are also available on the surplus market at a very low cost. E.g., Dubin Electronics Co., 103–02 Northern Blvd., Corona, N. Y.

TABLE I. Variation of half-period with amplitude.*

Amplitude, α (rad)	Measured half-period, t (sec)	Half-period for zero amplitude, t_0 (sec)
0.0366	1.003378	1.003286
.0306	1.003347	1.003284
.0258	1.003327	1.003281
.0218	1.003312	1.003280
.0184	1.003300	1.003276
.0156	1.003292	1.003276
.0132	1.003286	1.003274
.0110	1.003281	1.003273
.0091	1.003279	1.003273
.0078	1.003275	1.003270

* The reasons for this are not known but the difficulty might be traced to the shape of the knife-edge, the effect of the mercury contact or to some of the other factors discussed in reference 2.

an hour or two, results in an error of about 2 in the last decimal place of the half-period. This error is small when compared with other pendulum errors which are difficult to correct for.[2] The finite width of the mercury cup for electrical contact with the pendulum results in a series of 5 clicks of the sounder per coincidence when the amplitude of the pendulum is 0.035 rad and about 15 clicks when the amplitude is 0.009 rad. Sporadic clicks arising from local electrical disturbances are easy to distinguish from the regular clicks of a coincidence. The effect of temperature change is readily apparent in the results and so some effort must be made to avoid rapid temperature changes. On the assumption that the Kater's pendulum is made of steel, a rise of 1°C causes the half-period to increase about 6 parts per million.

The validity of the result has been confirmed by comparing the same pendulum with our standard pendulum-clock. For example, the half-periods, when measured at the same amplitude first by the radio receiver and then by the standard clock always agree to within 3 or 4 parts per million when corrected to the same temperature. The data obtained with the receiver have always been more consistent and reliable than the data obtained with the standard clock, probably because of the relays used in the standard-clock circuit.

No measurements have been made using any carrier frequency other than 5 Mc/sec. The 10 Mc/sec signal often appears strong here, however, and it might be advantageous to use it at certain times.

In connection with experiments of this type the following three items might be of interest:

(1) Since the 59th pulse of each minute is omitted by the transmitter, it is possible to check the behavior of the electric clock used. Variations of as much as three seconds were noted in the course of some experiments. Corrections were made for these variations. The use of a mechanical stop-watch would eliminate this difficulty, but the electric clock is much easier to use for a large number of readings.

(2) When the half-period of a Kater's pendulum is very close to one second, it is very difficult to tell by direct observation whether the half-period is greater than one or less than one. When measurements are made at different amplitudes, it is easy to distinguish between the two possibilities. Since the half-period always decreases as the amplitude decreases, it is easy to prove that, if the time between successive coincidences *increases* slightly as the amplitude decreases, the half-period is *greater* than one.

(3) The half-periods t_0, t for zero-amplitude and for a small finite amplitude α are related by the equation: $t=t_0(1+(\alpha^2/16))$. For the results obtained for different amplitudes the quantity $t/[1+(\alpha^2/16)]$ should be the same. This was not found to be the case, as is shown by the typical results of Table I.

[2] Mallock, *Proc. Roy. Soc.* **A85**, 505 (1911).

. . . if an individual scientist wants to make progress in his work, he must concentrate all his energy on one single task and for the time being forget completely other problems and interests. For this reason, never reproach the scholar too harshly for his other-worldliness and his indifference to important problems of human society. Without such a one-sided attitude, Heinrich Hertz could never have discovered radio waves, or Robert Koch the tubercle bacillus.—MAX PLANCK, "The Meaning and Limits of Exact Science," *Science* **110**, 319 (1949).

The History of Physics and the Old Humanism*

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A MODERN Erasmus, in a present-day *In Praise of Folly* would probably feel inclined to direct some of his critical remarks against men of science who demonstrate forcefully the necessity of a scientific education for everyone, but seem to be blind to the equal need of a broad education for themselves. The historical approach, for example, so widely advocated and propagated in the teaching of natural science as a cultural element in general education is only applied to the nonscientist, while the professional education of the scientist makes no effort to concern itself with historical considerations. It certainly cannot be denied that attempts to broaden scientific knowledge and to establish a true appreciation of scientific method in the layman are of great importance and should be welcomed. One has to realize, however, that the effort will remain futile in its wider aspects so long as the professional scientist fails to obey his own precept. It seems that very few scientists are interested in doing this, although it should be admitted that the idea is spreading.

Indeed, we have to ask ourselves if the education of the scientist for his presumptuous leadership in this "atomic age" is guaranteed through the present procedure of specialized instruction. Does the physicist or engineer, who learns more about scientific facts and theories, understand more of the general methods of science than the medical man or the man with a literary education? On the whole, the answer is now in the negative.

But even more important is the scientist's broader cultural education which cannot be effectively safeguarded by the prerequisites of his present college education. From the scientist, who takes upon himself the task of playing a conscious role in society and the state, there should consequently be demanded a philosophical penetration and a humanistic apprehension of the whole cultural field of which science forms a part.

* Presented under the title "History of Physics in the graduate curriculum" at the AAPT meeting at Seattle, June 30, 1949.

Unfortunately, scientists are sometimes less aware than others of the limitations of their knowledge. By their present specialized education they are led into a belief that their attitude is objective in every respect, and that all their actions are the outcome of this objectivity. They will often seriously contend that all answers can be supplied by science, and that it is a fallacy to assume that any constructive position can be established outside the sciences. Such an attitude makes the scientist unwilling to admit that he has to take steps in his education which would help to prepare him for the tasks he is going to assume.

It must, of course, be admitted that a student can get a broader education in a few of the existing colleges, but he most certainly will be handicapped when entering a graduate school where a purely technical preparation is demanded, and in such a graduate school he will hardly find the opportunity to pursue some of his broader interests. The issue before us is to provide in the specialized training programs of the graduate schools a niche in which the student can either gain or maintain a cultural education in close connection with his own field of studies.

The growing interest in "selling" the history of science to the nonscientist may have the effect that science teachers will have to study the development of their disciplines and perhaps they may find it not only profitable, but rather enjoyable to penetrate from here the easily accessible realm of humanistic studies. It is evident that such studies will be of permanent value for the students only if they are allowed to find a place in the senior and graduate curriculum, where they can contribute to the development of a more mature personality.

Historical Values

A course upon the history of physics can be considered an adequate means for achieving educational aims, but the teacher has to overcome serious difficulties. At the time when the science student might come into close contact with the

history of physics, he is, unfortunately, already too disinterested to ponder upon historical and philosophical subjects; he frequently terms these *speculation*. Perhaps the student's only contacts with historical topics have been introductory or marginal notes in text books, or occasional remarks by a teacher—neither always of an appreciative nature. Very often he has been told that the science of antiquity was purely speculative, that the Middle Ages followed similar dubious methods, that only since Galileo and Bacon has true science developed and dissipated ignorance and superstition.

Evidently the cumulative character of science is a disadvantage in this respect; the older layers of science pass quickly into oblivion, forming, as it were, the ballast of the road leading to scientific advancement. Whether this is also the road to human progress has yet to be seen. But obviously we have to take the trouble to search for evidences of the scientific past, and to arrange them like the archaeologist who fits together the fragments of a prehistoric time. In order to dispel some of the more popular misconceptions, it has to be shown at the outset in any history of science course that history is not merely a conglomeration of data and of so-called facts, but is able to provide a background for an appreciation of scientific and intellectual work and offers an easy approach to the world of history at large. By combining the story and the problems of the past with those of the present, a strong and permanent interest can be achieved.

The appreciation of historical ways of thinking, however, can be kept alive only if the attitude of the teacher is throughout one of sympathetic agreement, if it is shown that the historical development must not be judged by modern results and standards, and if dealing with events and thoughts of the past be done without any classification into important and unimportant, correct and incorrect. A history of physics has yet to be written with this freedom from preconceptions.

We have a difficult task to avoid the usual obsolete historical clichés which are so frequently offered and deal, for example, more sympathetically with Plato's scientific interests; and at the same time we shall be privileged to gain knowledge of the most influential philosophy of all times. We have opportunity to acquaint ourselves with Aristotle's teaching, and should not dismiss such a great thinker with no more than a shrug. We really have to ask ourselves: In what proportions does a student see the history of science as a whole when the picture of Plato and Aristotle, Democritus and Epicurus, or at a later period, of Descartes, is neglected to the point of concealment, or distorted beyond recognition? The same question is true for the treatment of whole epochs—the Roman times, or the Middle Ages.

It can never be just a question of showing "what these people *already* knew," or of expressing astonishment about the crudity and credulity of their knowledge and beliefs. We have to recognize the spirit of the science of the times and of their personalities. Only a sympathetic absorption in history will produce reverence for the development of human culture, as Dr. Sarton[1] has so very rightly reminded us; the reverence or respect of which Goethe said that it is the one faculty which we do not bring into this world, but which has to be acquired through education, and "on which all depends to make man in every respect into a human being."

Case Histories

Many problems of the present age become clearer when seen against a historical background, and on the other hand, the historical episode may gain fresh vigor when it is compared with contemporary events. Such a case is Galileo's trial which involves the question of the strength of the scientist's belief in *scientific truth.* Has a scientist ever been prepared to die for a scientific truth? History knows of a Socrates, a John Hus, a Giordano Bruno, a Michael Servet, and of a great number of religious, moral, and political martyrs. Galileo, who by his unwise behavior brought the trial upon himself, is the only scientist who in the past was ever called upon to demonstrate what kind of truth a scientific truth is. In his case it became apparent that it resembled a supposition rather than a conviction.

Looking at the trial from this angle, we hardly have reason to blame Galileo personally, except for his lack of foresight. He appears as the

[1] George Sarton, *The history of science and the new humanism* (Henry Holt, 1931), p. 68.

prototype of the scientist in relationship to the strength—or rather weakness—of his scientific belief. He appears quite human in his imprudence, and we can learn much humane understanding by following the intricacies of his life.

This question can be given an even broader setting by pointing out the earlier attitude of Copernicus. We are usually supposed to believe that Copernicus had cautiously declared the heliocentric system to be of a hypothetical character, because of the persecution which he dreaded from hostile Church authorities. Such fear, doubtless, was not without justification even in his time. But it is possible to maintain that Copernicus was a representative of the enlightened viewpoint, in agreement with the liberal, sceptical, and relativistic spirit of his age. For this historical period the two systems of the world were very much equivalent; not, of course, in the sense of the scientific relativism of Mach and Einstein, but in consequence of the sceptical relativism of the humanistic mind in the 16th century.

Copernicus was as much a son of his enlightened time as was Galileo of the more quarrelsome and rabid age of the counter-reformation. What an opportunity is here offered to get familiar with the humanists, with Erasmus' free criticism, and with the liberal tolerance of Montaigne. We may also easily detect a connection between Erasmus' critical studies in the *Novum Instrumentum* of 1516, and Bacon's *Novum Organum* of 1620, and perhaps we realize that the publication of the latter did not have quite the importance usually ascribed to it in scientific histories, in liberating thought from the influence of the "Schoolmen".

If biographies of Galileo and Copernicus offer for our considerations the problem and nature of a scientific truth, Newton's life story allows us to observe the scientific mind in trouble about the significance and the implications of his own findings, besides, of course, being in itself an important study of his great mathematical work. Newton's interest in religious matters, and the effects of "Newton's philosophy" on the educated class of the 18th century, are subjects having a close relationship to problems of our own time. We may find here the starting point of a discussion centering around "human destiny" and science, leading us from Newton through Voltaire, Rousseau, Comte, Herbert Spencer, to Planck, Eddington, Dean Inge, and DeNoüy.

To compare historical and sociological matters with contemporary issues we can choose the role of science and scientists in sociological speculation, beginning with Bacon's *The New Atlantis* continuing with Swift's *Laputa* of the 18th Century the *Erewhon* of the genial Samuel Butler of the 19th Century, and finally Aldous Huxley's frank *Brave New World* of recent fame. Or taking a more serious line we may consider the "scienticism" of Comte and St. Simon, and of the Technocrats, down to our own "atomic scientists" with their aspirations for a scientific world government. In any case, the "scienticism" of the modern vintage is becoming plainly understood only against the background of the utopian and sociological development out of which it grew.

The examples quoted (which can easily be increased) are *case histories* which can be placed in a more or less chronological order of didactic procedure. They do not, like Dr. Conant's case histories for nonscience students,[2] circle around a particular scientific question and its solution, but are related rather to human and social problems in a way that encourages a science student to branch out into fields which otherwise he would be unlikely to penetrate.

Humanism

I would even go so far as to say that a science student, who in a history of science course has read, in addition to his purely scientific studies, such books as Socrates' *Apology* (in Plato's words), or the *Phaedo*, or Aristotle's *Politics*; or Boëthius, Thomas Aquinas, Erasmus, Thomas More, Montaigne, Hobbes, Descartes, Spinoza, Rousseau, Goethe, and others, might find later that such reading has been the most valuable part of his work.[3] It seems to me that such reading and study would form for the modern scientist the necessary balance to offset his specialized education, now that he is conscious of political,

[2] James B. Conant, *On understanding science* (Yale Univ. Press, 1947).

[3] A list of books—not merely "great books"—useful for a broad history of physics (science) course has been prepared by the author in connection with a history of physics course, and can be obtained by request.

social, and human responsibilities. Only by the juxtaposition of scientific working methods and historical methods will he be made aware of their differences. Are we not, in the sciences, doing work with a real world, and is our research not aimed alone at discovering something which exists, which we only have to lift into the realm of knowledge? On the other hand, should not more of us be aware that in human, social, and political relations we have not to do with a prearranged world, and that all we create in these fields is brought about through determined human action? No automatic progress is here guaranteed as in the sciences; and to apply nothing but scientific considerations here would merely mean that

> . . . the native hue of resolution,
> Is sicklied o'er with the pale cast of thought.

The scientist who wishes to participate in politics cannot expect to find the marked signposts he is accustomed to find in his own fields. Here he is at any moment at the crossroads of moral decisions, and without the background of a study of human culture the scientist may become unknowingly the tool of other men's resoluteness. With a liberal education, based to a large degree on the noble humanism of antiquity, of the renaissance, and the period of enlightenment, he may be able to take a truly effective part in the events of his age.

Scientific progress, it seems to many of us, is based on a search for something existing but yet unknown; human progress is what *we* make of it. In other words, in the sciences we must be realists; in the practical humanities, in the spheres of economics and politics, we ought to be idealists. With these different patterns of values, it is extremely doubtful whether a "New Humanism" can develop out of the sciences, or arise from a study of history in which science is made the core of education and the implications of science are dangerously overemphasized. This is said with all respect to Dr. Sarton's important contribution of thirty years ago. A different effect can be expected only if we re-establish openly the *Old Humanism* in scientific education, and through it introduce this critical, liberal, and benevolent attitude which we consider to be the significant properties of the true humanist. Many will agree that the old humanism has served mankind well and that in the humanistic literature (to which parts of scientific literature certainly belong) are to be found values which cannot lightly be dismissed in our present situation.

Humanism, understood as an attitude of life, gives us the hope of re-establishing the dignity of the individual. Science, it can be admitted, has been a great instrument for increasing our knowledge and for improving the material side of man's life. But this progress has produced organizations and institutions which endanger the individual's integrity. We have to find a place for ideal humanistic values, so that the intellectual and moral integrity of the individual in a future universal society can be truly preserved. Even freedom in science is threatened today not merely from without, but also by the organizational leviathan into which science increasingly develops. A humanistic education *allied* to a scientific training, and with it the understanding of man as an entity of dignity, will also enable the individual scientist to maintain a position which will not be determined mainly by the interests of the group of which he is a member.

We could hardly hope for success if we were to suggest that the scientists' permanent studies should be pursued at the higher stages in the setting of a broad humanistic education. It might even be too much to expect that some allowance will be made for an approach to humanistic values through the medium of a liberal history of science course, as here suggested. Scientists, in their belief—not entirely unfounded—that they are marking history, are naturally prone to neglect the historical past. But we should consider the possibility that teaching science only as present-day "strategy and tactics" (to borrow Dr. Conant's phrase) might lead to the defeat of science in the full field of human activities in which the natural sciences seek to grow and prosper.

A Criticism of the Contemporary Physics Textbook

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THE textbooks of first-year college physics which are current today present an uncommonly attractive appearance. In the number and quality of diagrams and illustrations, the wealth and variety of topics treated, excellence of printing, and general appearance these modern textbooks far surpass those which were current, say, twenty years ago. However, in spite of this seemingly substantial improvement the usefulness of these very attractive books to the student is not as great as might be desired. In a recent article[1] Professor Perkins, himself the author of a widely used book,[2] has commented on the fact, painfully familiar to teachers of college physics, that students in a great many cases simply cannot read the textbook, and depend largely on their lecture notes in order to master the subject. He attributes this situation to the increasing illiteracy of our students, caused by progressive education, radio, the trend away from the printed word, and other similar factors. All of these, no doubt, play their part, but some degree of blame must be traceable to the textbook itself. Let us, then, consider what features of the current physics textbooks may be causing this unsatisfactory situation.

The chief defect of the modern textbook is its enormous length. In the attempt to be up-to-date, the authors have produced veritable encyclopedias running to seven or eight hundred pages. Such a mass of material cannot be covered, in any sense of the word, in two semesters, and students simply will not read through such lengthy volumes. The lecturer, therefore, "boils down" this vast accumulation to a small number of basic facts, principles, and techniques, and the textbook is used principally as a collection of problems. It is true, of course, that the more capable students will use it as a reference work, but even in these cases it would be better to have a book designed specifically for this purpose. One can, and in practice, does indicate to the students the sections that can be omitted and those that must be read, but the psychological effect of imbedding a small amount of necessary material in a great sea of fascinating but nonessential matter is not good, and in the end the student has to rely on the lecturer to limit and select the material. Inexperienced instructors frequently cannot do this themselves and, consequently, the prescribed material simply does not get covered.

One might ask why it is that the introductory physics text tends to assume such Gargantuan proportions. There are no doubt many causes, but the following seem the most important.

First, there is the desire to be modern and, therefore, to include a good deal of modern physics in the textbook. This is very seldom actually included in the introductory course, however, simply because of lack of time. If this material is included in the concluding chapters of the book the situation is not serious, since one can simply stop at that point, and the interested student may be urged to read this material on his own. It is a debatable question whether the time is now ripe to rework the entire structure of physics from a new viewpoint and thus reduce the volume of the material that has to be grasped. Such a reduction, by means of more powerful unifying principles, does in fact occur from time to time in the historical development of every science. But until such a reconstruction becomes possible, it is better to relegate atomic, nuclear, and other so-called "modern physics" to a separate course, since otherwise one has to sacrifice portions of classical physics without which the modern physics will rest on shaky foundations.

The second basic cause of great length in today's textbook is the desire to "sell" the subject to the student. This leads to the inclusion of material illustrating the applications of physics to industry, medicine, military matters, etc. This is sometimes carried to ridiculous lengths. A former colleague of the author used to say that he simply would not use any textbook that had a diagram of a hot water heating system in it, and many will agree that the point is well taken. It is prob-

[1] H. A. Perkins, "Observations of a 'reactionary' physics teacher," *Am. J. Physics* **17**, 376 (1949).

[2] H. A. Perkins, *College physics* (Prentice-Hall, ed. 3, 1948).

ably a carry-over of the progressive education ideas current in the high school, and at the college level simply clutters up the textbooks and distracts the attention of the student.

The third cause is the desire to make difficult matters clear to poorly prepared students which, while commendable in itself, often results in a sort of "talking-down" to the reader, an expedient also probably traceable to deteriorating standards in secondary education. The result is frequently a discussion so lengthy and diffuse that it defeats its very purpose. It is better to let the student ponder over a few well-chosen sentences than to have him struggle with a page of talking around and around a point.

Of the three causes listed above, the third is the least serious since it can be eliminated by a conscious effort on the part of the textbook writer. The first and second, however, present a really serious problem. It is obvious that both modern physics and applied physics are of vital importance, and that it is very desirable to let even the beginning student have some contact with them. But it would be better to concentrate this material in separate chapters, or even in a companion volume, entitled, let us say, "Readings in Modern and Applied Physics." Taylor's *Physics, the Pioneer Science*[3] could well serve as such a collateral textbook.

What then should the basic textbook in college physics be like? This, of course, depends on one's basic philosophy of physics. As a result of searching re-examinations of the foundations of physics, occasioned by the revolutionary developments of the current era, a fairly large degree of agreement exists among physicists on this point. The clearest statement of these matters is contained in the recent writings of Philipp Frank,[4] *Foundations of Physics*, and *Modern Science and its Philosophy*. According to this view, physics is a symbolic system which mirrors (partially, but ever more and more closely) the world of experience. The elements of this system are the concepts (e.g., mass, force, and charge), with their definitions, preferably operational, and the laws which relate them. With the aid of these, it is possible to make predictions of what will be observed under given conditions. While these matters have been discussed with adequate precision only in recent times, by Frank,[4] Bridgman,[5] and others, this has always been the procedure actually followed by physicists. It is reproduced in miniature in the familiar type of examination question which asks first to define certain entities, then to state a law involving them, and finally to solve a problem (i.e., make a prediction). It should be the principal aim of the textbook to make this clear, and to train the student in the technique which is involved. Of course, a certain amount of descriptive and historical material should precede the introduction of new concepts, but it is the logical (conceptual) structure that should be emphasized, since the learning of the descriptive material presents less of a problem. Two books, on the intermediate level, however, which fulfil very well the requirements here set forth are: Duff and Plimpton, *Elements of Electromagnetic Theory*,[6] and Lindsay, *General Physics for Students of Science*.[7]

In conclusion, it might be remarked that some of the older treatises were also quite long. For instance, the well-known and excellent text by Watson, *A Textbook of Physics*,[8] ran to 929 pages. However, Watson himself appears to have been aware, even in that day, that this length was excessive in anything but a reference work, and issued a shorter version, *General Physics*,[9] of 564 pages. In our own age, the drain on the student's time caused by the appearance of many new subjects and a less leisurely way of life makes it all the more desirable to have textbooks which will eliminate all nonessential material and exhibit as clearly as possible the basic framework of physics.

[3] L. W. Taylor, *Physics, the pioneer science* (Houghton-Mifflin, 1941).

[4] Philipp Frank, *Foundations of physics* (Chicago, 1946) and *Modern science and its philosophy* (Harvard, 1949).

[5] P. W. Bridgman, *The logic of modern physics* (Mac millan, 1927); *The nature of physical theory* (Princeton 1936).

[6] A. W. Duff and S. J. Plimpton, *Elements of electromagnetic theory* (Blakiston, 1940).

[7] R. B. Lindsay, *General physics for students of science* (Wiley, 1940).

[8] W. Watson, *A textbook of physics* (Longmans, Green, ed. 4, 1905).

[9] W. Watson, *General physics, New Ed.* (Longmans, Green, 1912).

An Experiment with an Oscillating Circuit Having Varying Capacitance

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EXPERIMENTS designed to illustrate the phenomena of oscillating systems with varying parameters must be chosen with care if useful quantitative results are to be obtained. Electrical circuits operating at audio frequencies are often most convenient for this purpose. Successful experiments with a resonant circuit having an inductance which varies with current,[1] and with an oscillator having a nonlinear negative resistance,[2] have already been described in these pages. The present paper contains a description of a resonant circuit in which the capacitance is made to vary as an independent function of time.

If the capacitance (or inductance) of a resonant circuit is caused to vary periodically at a rate twice the resonant frequency of the circuit, sustained oscillations may occur in the circuit at its resonant frequency.[3] In Fig. 1 is shown the variation of the capacitance and of the voltage across the capacitor in a typical case of this sort. The capacitance is caused to decrease at such times that it contains nearly maximum energy; in this way energy is supplied to the circuit to offset dissipative losses. The capacitance is caused to increase at such times that it contains little energy; thus not much energy is removed from the circuit during this part of the cycle. The usual mathematical treatment for a system of this kind is in terms of the Mathieu-Hill equations. A much simplified and inexact analysis follows.

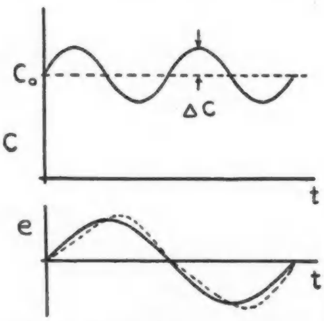

FIG. 1. Variation of capacitance with time and resulting voltage across capacitance in a resonant circuit. Dotted curve is a better approximation to voltage.

[1] W. J. Cunningham, *Am. J. Physics* **16**, 382 (1948).
[2] W. J. Cunningham, *Am. J. Physics* **18**, 208 (1950).
[3] N. Minorsky, *Nonlinear mechanics* (J. W. Edwards, Ann Arbor, 1947), Chapter XIX.

The parallel circuit of Fig. 2 will be considered. It may be described by the differential equation

$$C\dot{e}+\dot{C}e+e/R+(1/L)\int e dt=0, \tag{1}$$

where C, R, and L are the capacitance, resistance, and inductance as indicated, and e is the voltage across the parallel elements. The second term represents the component of current due to the variation of capacitance. If the capacitance is made to vary as a sinusoidal function of time at an angular frequency $2\omega_1$, it is given by the equation

$$C=C_0(1+a\sin 2\omega_1 t), \tag{2}$$

where C_0 is the mean capacitance, and $a=\Delta C/C_0$ is the relative variation. Substitution of Eq. (2) into Eq. (1) and simplification gives the result

$$(1+a\sin 2\omega_1 t)\dot{e}+(2\omega_1 a\cos 2\omega_1 t+b)e +\omega_0^2\int e dt=0, \tag{3}$$

where $b\equiv 1/RC_0$ and $\omega_0^2\equiv 1/LC_0$. Since Eq. (3) has terms with coefficients varying with time, its solution is not easily obtained. An approximate solution is

$$e=E\sin\omega_1 t. \tag{4}$$

This approximate solution may be substituted into Eq. (3), use made of the identities,

$$\sin 2\omega_1 t\cos\omega_1 t=\tfrac{1}{2}(\sin 3\omega_1 t+\sin\omega_1 t)$$
$$\cos 2\omega_1 t\sin\omega_1 t=\tfrac{1}{2}(\sin 3\omega_1 t-\sin\omega_1 t),$$

and terms collected to give the result

$$(\omega_1^2-\omega_0^2)\cos\omega_1 t-(a\omega_1^2/2-b\omega_1)\sin\omega_1 t +(3a\omega_1^2/2)\sin 3\omega_1 t=0. \tag{5}$$

This equation must hold at all times, so that coefficients of individual terms must be zero.

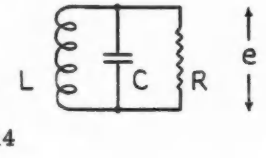

FIG. 2. Parallel resonant circuit in which capacitance is caused to vary with time.

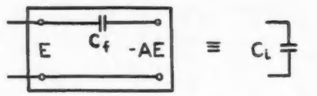

FIG. 3. Amplifier with internal capacitive feedback so as to give an input capacitance C_i.

Therefore, the following results are obtained,

$$\omega_1=\omega_0, \tag{6}$$

$$a=2b/\omega_1=2/\omega_1 RC_0. \tag{7}$$

The frequency of oscillation in the circuit is the same as the resonant frequency, from Eq. (6), and the relative variation in capacitance needed to maintain oscillation is given by Eq. (7). Both these equations are only approximate because the solution assumed in Eq. (4) is only approximate. Also for this reason, the term in $3\omega_1 t$ is ignored, for its coefficient obviously cannot be zero. A somewhat better solution would be that of Eq. (4) with an additional term of frequency $3\omega_1 t$, but the analysis becomes considerably more complicated with the added term. The dotted curve of Fig. 1 shows the more accurate form for the voltage e. The amplitude E of the oscillation remains unknown since it disappears in the analysis. If $a>2b/\omega_1$, energy is constantly supplied to the circuit, and the amplitude will increase indefinitely until limited by some nonlinearity not considered here.

A circuit for demonstrating the phenomenon just described must have provision for varying a capacitance with time. The most flexible way of doing this is by the use of an electronic feedback circuit similar to the reactance tube of frequency-modulation systems. A single-stage vacuum-tube amplifier, with high input impedance and low output impedance, has a voltage amplification $-A$. The negative sign indicates the reversal of phase common to this type amplifier. If a capacitance C_f is connected between output and input terminals of the amplifier, as in Fig. 3, the input impedance of the amplifier will be that of a capacitance given by[4]

$$C_i=C_f(1+A). \tag{8}$$

There also will be a resistive component to the input impedance, determined by the resistance

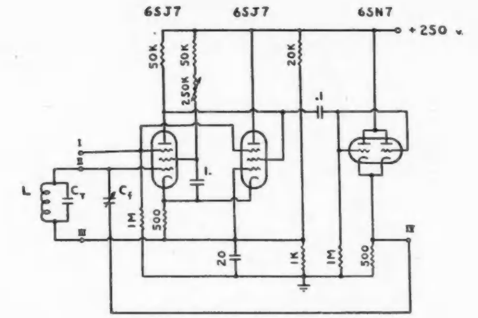

FIG. 4. Amplifier designed to have a gain between terminals II and IV controllable by a voltage applied to terminal I. Balancing action prevents the signal at terminal I from appearing at terminal IV. Units of resistance are ohms, of capacitance are microfarads.

in the circuit and small phase shifts which are present. It is evident from Eq. (8) that capacitance C_i may be varied if the amplification A is varied. This is easily done by controlling a bias voltage of the tube used in the amplifier, thus making C_i dependent upon a voltage. Capacitance C_i can be used as a portion of the capacitance in the oscillating circuit of Fig. 2.

Unfortunately for the present purpose, variation of a bias voltage produces variation of plate current, and a corresponding signal appears at the output of the amplifier. If a voltage of frequency $2\omega_1$ is used to vary A and C_i, an undesired signal of this frequency will appear across the terminals of C_i unless special provisions are made. A balanced modulator circuit, operated with cancellation of the modulating signal, is a circuit wherein the undesired signal is suppressed. Such a balanced modulator could be used successfully as the amplifier. However this type of circuit requires a pair of carefully matched transformers which are relatively expensive and are likely to pick up hum. For that reason another form of circuit is used here.

The circuit for an experimental amplifier with a balancing arrangement is shown in Fig. 4. It is a modification of a circuit which has already been described.[5] While it is more complex than might be desired, good balancing action is obtained without the use of special components. There are three tubes in the circuit, of which only the first 6SJ7 pentode is the amplifier. The second 6SJ7

[4] H. J. Reich, *Theory and applications of electron tubes* (McGraw-Hill, New York, 1944), p. 214.

[5] W. H. Stevens, *Wireless Engineer* **21**, 10 (1944).

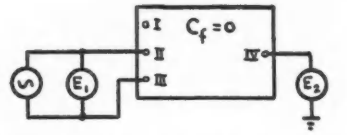

FIG. 5. Test circuit for measuring gain of amplifier.

pentode is a balancing tube, and the 6SN7 double triode is a cathode follower used to give a low output impedance. The amplification of the circuit is controlled by the voltage applied to the suppressor grids of the pentodes. The balancing action of the second pentode takes place because the suppressor voltage controls the division of current between plate and screen grid of a pentode. If the suppressors are made more negative, the first plate draws less current but the second screen draws more current. Since these two elements are connected together, the total current through the load resistor of the first pentode may be constant for changes in suppressor voltage. The amplification of a signal applied to the control grid is smaller for a more negative suppressor voltage and may be changed within fairly wide limits. Capacitance C_f, in conjunction with the amplifier, provides a variable capacitance C_i between the terminals II and III.

No special precautions are needed in setting up the amplifier. If a tendency for oscillation at a very high frequency appears, a small capacitance from the plate of the first pentode to ground should restore stability. The balancing action may be adjusted by applying an audio frequency signal of several volts between terminal I and ground, and observing the output signal between terminal IV and ground. Capacitance C_f should be zero for these tests. It should be possible to adjust the screen voltage of the first pentode so as to make the output signal almost vanish. Since the balancing effect is dependent upon rather special properties of pentodes, several sets of 6SJ7 tubes may have to be tried in order to obtain best results. Once adjusted, the balancing control requires no further attention.

The oscillating circuit is composed of the inductance L and the capacitance C_T in conjunction with the variable input capacitance C_i of the amplifier. The inductance should have low resistance, but should not have an iron core, which might show effects of magnetic saturation.

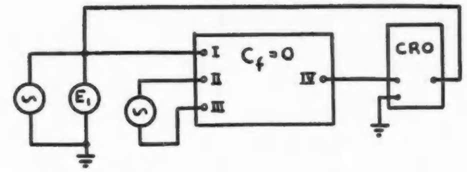

FIG. 6. Test circuit for measuring variation in gain of amplifier.

Element values should be chosen so that the resonant frequency is in the middle audio range. An experiment demonstrating oscillations produced by the variable capacitance may be performed in the following way.

First, the voltage amplification of the amplifier alone is measured. A generator and two voltmeters are connected as shown in Fig. 5, with capacitance C_f set to zero. It should be noted that terminal III is not at d.c. ground potential, and that the generator must have a d.c. path between its terminals. Input and output voltages of the amplifier should be measured at a frequency near the resonant frequency to be studied. The amplification is given by

$$A = E_2/E_1. \tag{9}$$

Second, the variation in gain of the amplifier is measured as a function of the voltage applied to terminal I. It is most convenient to do this dynamically with two generators as shown in Fig. 6. A signal of frequency near that of the resonant circuit is applied between terminals II and III. Its amplitude is modulated by a signal of lower frequency applied to terminal I. Capacitance C_f should be set to zero. A trapezoidal figure is produced on the screen of the oscilloscope.[6] The modulation index m is given by

$$m = (X - Y)/(X + Y), \tag{10}$$

where X and Y are the lengths of the long and short sides of the trapezoid.

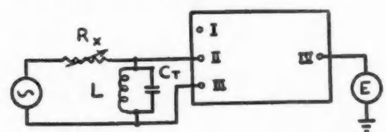

FIG. 7. Test circuit for measuring resonant frequency and parallel resistance of oscillating circuit.

[6] F. E. Terman, *Radio engineers' handbook* (McGraw-Hill, New York, 1943), p. 988.

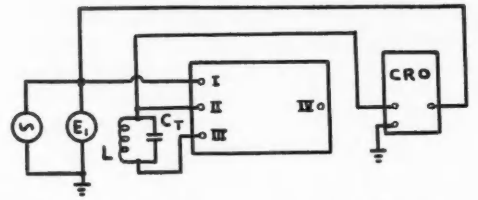

FIG. 8. Circuit for producing and observing oscillations produced by variation of capacitance in oscillating circuit.

Third, the parallel resistance R of the oscillating circuit must be measured at its resonant frequency. A simple means of doing this is shown in Fig. 7. The oscillating circuit is connected to the amplifier and is supplied with a signal from a generator with a series resistance R_x. The generator is tuned to the resonant frequency of the circuit (most easily done with R_x large) as indicated by maximum output voltage. The value of R_x needed to reduce the output signal to half the amplitude it has with R_x zero, is the resistance R for the circuit. A measurement should be made of R for each value of C_f to be studied.

Fourth, oscillations due to varying capacitance are obtained using the circuit of Fig. 8. The generator must provide a signal to terminal I at twice the resonant frequency of the oscillating circuit. The generator frequency and voltage must be adjusted carefully to produce the type of oscillations sought. Measurements should be made of the generator frequency and voltage as a function of the capacitance C_f, with oscillations at the lowest possible amplitude. The two-to-one relation between the frequencies of the generator and the oscillation in the circuit may be checked from the Lissajous figure on the oscilloscope. At the same time the phase relation used in Eq. (2) and Eq. (4) of the mathematical analysis can be checked. Observation of the wave form of the oscillations, using a linear time base, shows them to be nearly sinusoidal but with a third harmonic large enough to be identified readily. An electronic switch can be used in conjunction with the oscilloscope to obtain a pattern similar to Fig. 1.

TABLE I. Typical experimental data for several values of C_f.

C_f μf	E_1 v	m	ΔC μf	C_i μf	C_0 μf	f_0 cycle/sec	f_1 cycle/sec	R Ω	$\frac{2}{\omega_1 R C_0}$	a
0.002	8.1	0.59	0.021	0.037	0.137	1200	1220	12700	0.15	0.15
0.007	4.9	0.35	0.043	0.13	0.23	930	950	8000	0.18	0.19
0.013	4.8	0.34	0.078	0.24	0.34	760	790	5400	0.23	0.24

$A=17.5$
m is given in Fig. 9
$L=0.128$ henry, $Q=13$ at frequency of 1000 cycle sec^{-1}
$C_T=0.1$ μf
$C_0=C_i+C_T$
$\Delta C=mAC_f=aC_0$

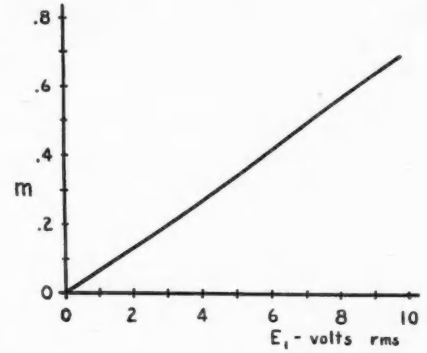

FIG. 9. Modulation index for amplifier of Fig. 4 as a function of rms voltage applied to terminal I.

A typical set of experimental data is given in Table I. In the table E_1 is the voltage of the generator applied to terminal I, and f_1 is the frequency of the oscillation (half the generator frequency). According to Eq. (7), the last two columns of the table should be the same; the agreement is seen to be satisfactory here. If C_f is made too large the agreement becomes poorer, while if C_f is made too small no oscillation is possible. The resonant frequency f_0 of the circuit can be observed during the third part of the experiment, or may be calculated from L and C_0. It is always slightly lower than the oscillating frequency, indicating the inexactness of Eq. (6).

The most likely source of difficulty in using the circuit lies in the effect of variation in amplitude of the oscillation. As mentioned previously, the amplitude will increase so long as the system is linear. The cathode-follower circuit has been designed intentionally so it will overload at a relatively small signal voltage, and thus provide a limiting action. There is a small effect in the pentode amplifier, however, which tends to reduce the amplification as the amplitude increases. This effect results in a decrease in C_i as oscillations build up. Therefore, the jump phenomenon[7] characteristic of resonant circuits with parameters a function of amplitude may appear. In

[7] W. J. Cunningham, reference 1.

making measurements it is desirable always to keep the amplitude as small as possible.

Modification of the experimental procedure outlined here are obviously possible. For example, instead of measuring the variation in amplification dynamically, as in the second part, a static measurement in terms of a steady voltage applied to terminal I could be used. Similarly, instead of calculating the capacitance C_i from a knowledge of C_f and A, a direct measurement could be made with an impedance bridge.

In conclusion it may be observed that the experimental circuit can be considered from an entirely different viewpoint. The amplifier with its variable gain serves essentially as a modulator operating at a frequency $2f_1$. A signal of frequency f_1 applied to the amplifier input will be modulated and will produce a pair of side frequencies at f_1 and $3f_1$. The first of these is the original frequency, which is selected by the resonant circuit and is used to supply the original signal. The oscillations are therefore self-sustaining. This type of modulator system has been used in frequency-divider applications.[8]

[8] F. R. Stansel, *Proc. I.R.E.* **30**, 157 (1942).

RECENT MEETINGS

Western Pennsylvania Section

The fall meeting of the Western Pennsylvania Section of the American Association of Physics Teachers was held at the University of Pittsburgh, Pittsburgh, Pa., on December 3, 1949. Forty-six members and guests were welcomed by Dr. Blackwood of the Physics Department, *University of Pittsburgh*. The program follows:

Steinheil spectroscope of 65 years ago. Howard Long, *Washington and Jefferson University.*

Spinning tops. R. C. Colwell, *West Virginia University.*

Oscilloscope display of damped oscillation curves. Charles Williamson, *Carnegie Institute of Technology.*

Various applications of the multiplier photocell. L. D. Fallon, *Geneva College.*

Gyroscopic action. W. H. Michener, *Allegheny College.*

Summer student employment at Westinghouse. R. E. Warren, *Westinghouse Research Laboratories.*

Projects for physics majors. W. C. Kelly, *University of Pittsburgh.*

Atoms demonstration. Staley and Shriner, *Carnegie Institute of Technology.*

Apparatus for demonstrating and mapping an electric field. Rev. B. Brinker, *St. Vincent's.*

Tribulations of a textbook writer. O. Blackwood, *University of Pittsburgh.*

Reminiscences of graduate school at Michigan. W. St. Peter, *University of Pittsburgh.*

By means of a resolution endorsed by Raymond M. Bell, *Washington and Jefferson University*, the Section expressed its great sorrow and regret at the passing of Professor A. G. Worthing.

The meeting adjourned with an invitation from the host to visit the Cyclotron Laboratory under the guidance or Dr. J. Kelly.

Luncheon was served in the Faculty Club Rooms and was followed by a business meeting. Officers elected for the coming year were: *President*, A. J. Kozora, *Duquesne University; Vice-President*, J. Kelly, *University of Pittsburgh; Secretary*, R. E. Warren, *Westinghouse Research Laboratories; Representative to Executive Committee*, Rev. B. Brinker, *St. Vincent's College.*

Andrew J. Kozora, *Secretary*

Kentucky Section

The annual fall meeting of the Kentucky Section of the American Association of Physics Teachers was held on November 5, 1949 at the Physics Building of Centre College, Danville, Kentucky. Twenty-eight members and guests attended. R. A. Loring, President of the Section, presided during the presentation of the following papers:

Dimensional systems. Otis Wolfe, *Centre College.*

Leibnitz's formula for perfect knowledge. P. C. Overstreet, *Morehead State College.*

A method of presenting equations of projectile motion. F. W. Parker, *Lincoln Memorial University.*

Acoustic absorption and molecular theory. C. E. Adams, *University of Louisville.*

Two experiments on kinetic theory of gases for demonstration and advanced laboratory. E. G. Andresen, *University of Louisville.*

A gradual approach to abstract reasoning. D. M. Bennett, *University of Louisville.*

Some optical properties of crystalline quartz. C. T. Maney and R. Hanau, *University of Kentucky.*

Notes on the Michelson interferometer. R. A. Loring, *University of Louisville.*

The meeting closed with a luncheon in the Centre College dining hall. The next meeting of the Section will be held in April, 1950 in conjunction with the annual meeting of the Kentucky Education Association.

L. W. Cochran, *Secretary*

NOTES AND DISCUSSION

A Dynamic Demonstration of Nitrogen Afterglow

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University of California, Berkeley 4, California

IN the process of building a small radiofrequency power supply, the base of an ordinary 200-w (incandescent type) light bulb was placed in contact with the ungrounded end of the output coil. Several long jets of glowing gas were observed to shoot from the filament. These had the appearance of orange gas flames and not of electric discharges. When the power was abruptly removed from the lamp (by by-passing through a metal rod held in the hand), swirling clouds of glowing gas could be seen throughout the bulb for several seconds. Here was a clear case of afterglow and it seemed likely that it was the nitrogen (with which modern lamps are partly filled to slow the evaporation of the tungsten filament) that was activated. Since the electric field was strongest in the region of any bend in the filament, it was from these bends that the jets emanated. Convection currents within the bulb caused these glowing streamers to move around in a most beautiful and spectacular way. Often a piece of a jet would detach itself and momentarily leave a small luminous nebulosity drifting about in the bulb. Occasionally an inverted "Jacob's ladder"-like effect was noted along a filament support. To see a common object behave in such an unexpected way arouses much interest and the use of an ordinary light bulb is considerably more effective than any special tube would be.

The production and properties of activated nitrogen have been subjects of investigation for many years. Most theories have assumed that the active particles are either nitrogen atoms, metastable nitrogen molecules, or some combination of the two. Possibly the best and most complete summary of the work on active nitrogen is that given by S. K. Mitra in his paper[1] "Active Nitrogen—A New Theory." In this paper he suggests the active material to be positive ions of nitrogen molecules. He suggests that the walls of the containing vessel become conditioned by a layer of nitrogen so that they do not collect electrons with which to neutralize the ions. In general, there will be required an unlikely three-body collision for neutralization to take place anywhere except at the walls (in order that momentum and energy both be conserved) and this is his explanation for the long life of the ions. In some experiments to determine the order of the reaction involved, Kneser[2] experimented with varying proportions of argon and nitrogen at varying pressures. Though none of his mixtures approached the conditions in the light bulbs under our consideration (86 percent argon, 14 percent nitrogen at about 0.7 atmos.), it is not unexpected to find a rather short-duration glow of good intensity in these bulbs.

Afterglowing nitrogen is characterized by a spectrum of bands in the red, yellow, and green, each of about the same intensity. Such bands were observed in the spectrum of the glowing gas in the light bulbs. It is known that the appearance of nitrogen afterglow is somewhat greenish in the presence of oxygen. However, the gas in a light bulb includes little of this, and so the golden-yellow color is observed. The spherical geometry of a light bulb is advantageous in that it reduces the effect of the walls in stopping the glow.

Some practical details of the present experiment should perhaps be discussed. The above-mentioned power supply consisted of a small pair of windings (occupying about 1 cubic inch) used as a step-up transformer, the primary of which was driven at the resonant frequency of the secondary (i.e., at the frequency for which the stray capacitance of the secondary resonated with its inductance). The oscillator made use of a Type 6L6 tube in a Colpitts circuit and drew about 100 ma at 350 v. The output voltage was about 5000 v. The frequency for this particular coil (which could have been a regular r-f power-supply coil but in this case was a converted input transformer) was of the order of 200 kc. However, the frequency is apparently not critical as a 20-Mc oscillator worked as well (though a "leak tester" did not excite afterglow at all). A more powerful oscillator quickly fills the whole tube with glowing gas, but the effect is not as pretty due to the loss of the streamers. The effect seems quite reproducible in that all the 150- and 200-w bulbs that were available with the label "General Electric" or "Champion" showed the phenomenon. Of course, this was not true of smaller evacuated bulbs. One set of 150-w bulbs labeled "Ken-Rad" exhibited a pink discharge near bends in the filament but did not show the above effects.

It might not be inappropriate to mention that such r-f power oscillators are suitable for all Tesla coil experiments such as lighting fluorescent lamps at a distance without wires, drawing sparks to hand-held metal rods, driving electric whirls, lighting hand-held incandescent lamps, lighting neon or other bulbs held between two people one of whom is taking the discharge, producing ring discharges in neon bulbs, etc. Further, they are much more quiet and pleasant to work with than the usual Tesla coil. A bulb containing neon, to which a drop of mercury has been added, is interesting in that it shows a blue or red discharge depending on its distance to the coil. With a somewhat higher power oscillator than above described, one can use the loop of one's arms as a one-turn secondary to light an incandescent lamp held in the fingers (as opposed to the above-mentioned experiment of lighting a bulb by letting a spark jump to the tip of the base and the current come out of the screw part into the hand). Though a large number of volts per turn are required, it is also possible to cause small sparks to jump between the fingertips while using the arms as the secondary "winding" of a transformer.

[1] The Joykissen Mookerjee Medal Lecture for 1945, published by the Indian Association for Cultivation of Science.
[2] Kneser, *Ann. der Physik* **87**, 717 (1928).

A Modification of Rayleigh's Method of Measuring Surface Tension

PAUL F. BARTUNEK
Lehigh University, Bethlehem, Pennsylvania

RAYLEIGH'S method of measuring the surface tension of a liquid depends upon a measurement of the wavelength of ripples formed on the surface of the liquid whose surface tension is to be determined. The well-known theoretical expression for the velocity v of a harmonic disturbance on the surface of a liquid is

$$v=\left(\frac{g\lambda}{2\pi}\tanh\frac{2\pi h}{\lambda}+\frac{2\pi T}{\lambda\rho}\right)^{\frac{1}{2}}, \tag{1}$$

where g is the acceleration due to gravity, λ the wavelength, h the depth of the liquid, ρ the density of the liquid, and T the surface tension. The factor $\tanh(2\pi h/\lambda)$ can be dropped if h is equal to or greater than λ since its value then differs from unity by less than one part in ten thousand. The method, first used by Lord Rayleigh, of measuring the wavelength was to set up the ripples with one tuning fork, then use another similar fork to provide intermittent views of the surface.[1] The ripples are set up by means of an electrically maintained tuning fork arranged near one end of the containing vessel. Attached to one prong of the fork is a thin sheet of metal foil dipping into the liquid. To obtain intermittent views of the surface of the liquid, the second fork is provided with two thin pieces of metal foil arranged so that a direct view of the surface is provided only when the prongs of this fork are at maximum separation. The two forks are driven from the same electric circuit. Thus, an apparently stationary set of waves is seen when the surface is viewed in this way. The wavelength can then be obtained by direct measurement of a number of waves by dividers adjusted over the surface. Putting $v=n\lambda$ into Eq. (1), where n is the known frequency of the forks, one can solve for T.

The simplification developed by the author while he was a staff member at Rensselaer Polytechnic Institute and tested by his advanced students consists of (1) substitution of an a.c. driven vibrator in place of the exciting fork of Rayleigh's original method and (2) substitution of an intermittent neon flasher in place of the viewing fork. The arrangement is shown schematically in Fig. 1. The advantages of the modified method lie in (1) elimination of the viewing fork thus reducing the amount of moving mechanism and (2) elimination of the troublesome intermittent contact. In this modification n is twice the line frequency, i.e., 120 cycles/sec, which should be checked carefully with an indicator each time measurements are taken. This simple method yields surprisingly accurate results.

For the benefit of those readers who may be interested in elaborations of the ripple method two interesting papers may be mentioned. The first of these, by Brown,[2] contains a bibliography of the papers published up to 1936, and describes various techniques as well as an interesting and elaborate method of Brown's. The second paper, by Tyler,[3] likewise gives a general discussion, describes various methods and elaborate experimental arrangements. In addition, some graphical methods of reducing the data are set forth.

1 Worsnop and Flint, *Advanced practical physics for students* (Methuen, Ed. 3), pp. 137–140.
2 R. C. Brown, *Proc. Physical Soc., London* **48**, 312 (1936).
3 E. Tyler, *Phil. Mag.* **31**, 209 (1941).

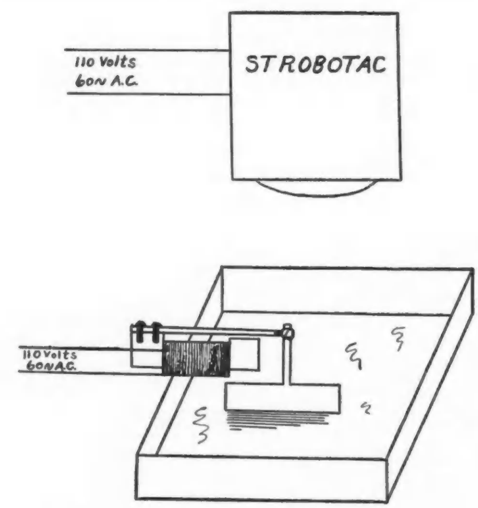

FIG. 1. A Modification of Rayleigh's method for measurement of surface tension.

A Simple Derivation of the Formula for the Mean Collision Number of Molecules on a Wall

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THE mean collision number per unit area per unit time is usually calculated for the case of a plane wall. A simpler derivation may be obtained by considering the collision number on a sphere.

Let N be the number of molecules per unit volume and r the radius of the sphere. The sphere offers a target of the same size, πr^2, whatever the direction of motion of a

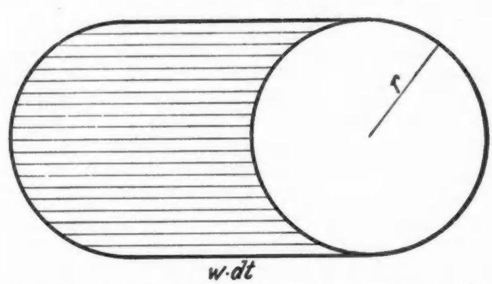

FIG. 1. Cross section of a sphere and the space containing all the molecules that will hit the sphere within the time dt.

molecule may be. The mean collision number on the sphere would therefore remain unaltered if all the molecules were moving in one direction, provided the distribution of molecules in space were still random. In Fig. 1, which represents a cross section of the sphere, all the molecules are thought of as moving from left to right with the velocity w. Of all the molecules aiming at the sphere, those having a distance to travel which is shorter than wdt will hit the sphere in the time dt. These molecules are contained in a volume $\pi r^2 wdt$. The number of molecules contained in this volume is $N\pi r^2 wdt$ which accordingly is the collision number on the sphere in the time dt.

These collisions are actually distributed all over the sphere, and division by the area of the surface of the sphere, $4\pi r^2$, and by dt, will give the desired quantity in the form $\frac{1}{4}Nw$. For the sake of simplicity, all the molecules have been supposed to move with velocity w. However, it is easily seen that the derivation is valid for a Maxwellian distribution of velocities if w is taken as the average velocity.

The analogy between the method described and Barbier's solution of Buffon's needle problem may be noticed.[1] This problem deals with the probable number of intersections between a set of equidistant, parallel lines and a straight needle, thrown at random. Barbier argues that the probable number of intersections per unit length of the needle is the same irrespective of its shape. Instead of calculating the probable number of intersections for a straight needle, he chooses one curved in a circle, just as in the derivation above a sphere was chosen instead of a plane wall.

[1] J. V. Uspensky, *Introduction to mathematical probability* (McGraw-Hill, 1937), p. 253.

AMERICAN JOURNAL OF PHYSICS VOLUME 18, NUMBER 5 MAY, 1950

LETTERS TO THE EDITOR

Conversion Charts

THE use of conversion charts for beginners proposed in the paper by Hitchcock and Ure[1] seems to run contrary to the fundamentals of good science instruction. Nomographs, charts, formulas, and other shortcuts are pedagogically sound only if the student understands the underlying principle. Otherwise the auxilliary device acts as a mental crutch.

The proper use of units and their conversion from one system into another is one of the specific objectives of a course in elementary physics. Yet it is hard to see how the conversion charts will make any contribution toward that objective. Suppose the student is asked to work the following example: "Convert the charge of an electron (4.8×10^{-10} statcoulomb) into m.k.s. units." Then the problem is slightly more complicated if the charts are used than it would be if the conversion factor had been used in the first place. The student must modify the scale *and* find the proper multiplying factor. The necessity for using *conversion factors*, or calculating them from the charts, becomes clear upon examination of Figs. 5 and 11, where the smallest scale divisions are 10^{16} Mev and 10^{8} farad on the Mev and farad scales respectively!

The conversion charts may have applications wherever many routine conversions are needed; they might be useful in advanced work for checking calculations or in a laboratory doing routine testing. But even there these are hardly usable "conversion" charts. No accurate numerical values can be read from them. Conversion factors will need to be used and these charts then will tell you whether or not some gross blunder such as multiplying instead of dividing has been made. As for beginners, there is no substitute, in my opinion, for the basic mental operations.

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[1] *Am. J. Physics* **17**, 551 (1949).

Teaching Alternating Current Circuits

IN a recent paper "Teaching Alternating Current Circuits"[1] the term "vector" is applied to various circuit quantities in describing a teaching procedure intended for elementary students, without clearly expressing the limitations of this terminology. Unless such limitations are clearly explained to the beginning student, he is likely to acquire some erroneous impressions; *e.g.*, that the relations between circuit quantities are the relations of ordinary vector algebra in two dimensions, or even that the quotient of two arbitrary vectors may be obtained.

Alternating current and voltage are scalar functions of time whose relationships can be expressed by the operations of complex algebra. Vectors in a plane and complex variables have the same rules for addition, but the operation of multiplication is not the same for both, and the operation of division is not even defined for vectors. Colloquial use of vector terminology probably causes little confusion to those who are already familiar with circuit theory, but when used with elementary students, such usage is at best a crutch, the use of a familiar term leading the student to believe he understands something which he really does not understand. Careless usage may muddle fundamental concepts, and cause later confusion between the "a.c. vector" quantities voltage, current, etc., and physical vector quantities such as potential gradient, current density, etc.

This writer knows of several capable students who were first taught "a.c. vectors" in courses where the distinction between these quantities and ordinary vector quantities was not clearly emphasized, and who thereby experienced much unnecessary difficulty when they first encountered the concepts of elementary vector analysis in intermediate physics courses. Let their confusion stand as evidence that this point is neither obvious to the beginning student, nor too trivial to be emphasized to students. It seems just as

important to use vector terminology with scrupulous accuracy and within clearly stated limitations (if it is to be used at all) in papers addressed to the teachers of elementary students.

Colloquial usage may be reconciled with correctness by use of a statement such as the following: "Alternating current circuit quantities such as voltage, current, and impedance can be added like ordinary vector quantities when suitable direction conventions have been adopted, and each may be referred to as a vector quantity for the purpose of addition to like quantities, but the relations involving different quantities, such as Ohm's law, are not vector relations."

In the paper cited, however, the limitations upon vector terminology are not emphasized. Indeed, the following sentence appears (p. 506): "Voltage and current are ordinary vectors but sometimes called phasors, and impedance is a multiplier such that $V=ZI$."

Regarding this statement and its context, several comments may be made. The equation $V=ZI$ is not a vector equation, and since complex algebra has been avoided by the authors of this paper, the equation as used in the paper boils down to a simple algebraic expression in the magnitudes only. The elementary student would benefit from a clear statement of this fact. The equation might even helpfully be rewritten

$$|V|=|Z|\,|I|.$$

The circuit quantities, voltage and current, are not "ordinary vectors" as stated, nor yet ordinary vector quantities, except within the framework of some statement of limitations as expressed above. But, in this sense, impedance is no less a vector quantity than are current and voltage, and contrary to implication in the paper, the three may be considered on an equivalent basis.

This writer would suggest that the study of parallel impedances might be facilitated if the students were introduced (with suitable direction conventions) to the concept of admittance, a quantity whose magnitude is $|Z|^{-1}$. (Of course, one must convince the student that he is not thereby taking the reciprocal of a vector quantity, merely that of a magnitude.) If the student is reminded that when d.c. resistances are connected in parallel, the conductance of the group is the sum of the individual conductances, he will find it easy to remember that the admittance of a group of parallel a.c. impedances is the vector sum of the individual admittances. He now has a name for the quantities he must calculate in any case, using the method described in the paper.

The quantities voltage, current, impedance, and if desired, admittance, can all be considered on an entirely equivalent basis: Each can be added to like quantities by vector addition under suitable direction conventions. The consistency gained thereby should be helpful if one is committed to the objective of teaching series-parallel alternating current circuits without the use of complex algebra.

The use of vector terminology places upon the instructor an obligation to explain its limitations. But if students are mature enough to understand such an explanation, it may be possible to teach them the somewhat more generally useful complex algebraic method which, for series-parallel circuits, need involve no mathematics beyond $i^2=-1$. It would be interesting to have comments regarding the relative teachability of these two methods by teachers who have used both.

It is entirely possible, perhaps even desirable, to teach alternating current circuits, even by the method described in this paper, without mentioning the word "vector," using instead such descriptive terms as "phase diagram," "impedance diagram," "phasor," etc. However, if vector terminology is to be used, confusion in later courses can be minimized only if it is used correctly and within clearly expressed limitations.

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[1] Winans, Cole, Walters, and Hummel, *Am. J. Physics* **17**, 503 (1949).

Does Pressure Have Direction?

REGARDING the controversy as to whether or not pressure has direction which has appeared in the *American Journal of Physics*[1] the following remarks appear to be in order:

1. If, as proposed by Summers in his original article, pressure is to be regarded as the scalar result of dividing force (a vector) by area (a vector), trouble will be encountered when, in the case of stress, the result of the same division must be designated as a vector.

2. The analogy implied in the original paper between Leacock's horseman who "rode madly off in all directions" and the idea that the pressure at a point in a static fluid is equal in all directions is not valid. This is so since there appears to be no limit to the number of directions from which pressure or force may be regarded as acting on a point, while motion of a particle in more than one direction, except from the standpoint of relativity, is absurd.

3. There appears to be little validity to the argument presented by Summers in his reply to the letter by Barton that "If p represents the pressure and v the volume of a substance, $\int pdv$ equals . . . the external work of expansion." and that, if pressure is a vector quantity, one would have a scalar, work, as the result of the product of a vector quantity, the pressure, by a scalar quantity, the volume. The inapplicability of this argument is to be seen upon recalling that work is the scalar product of two vectors: the force performing the work and the displacement produced. If, using Cartesian coordinates, the displacement takes place in the x-direction, the work done on the element of area $dydz$ would, assuming pressure to be a vector quantity, be given by the expression: $dydz\,(\int \mathbf{p}\cdot d\mathbf{x})$. Since, for perfect fluids, the pressure acts normally to the surface, one then finds that the work on the element of area $dydz$ is $dydz\,(\int pdx)$, or, integrating over the whole surface, the total work would be $\int\int\int pdxdydz=\int pdv$. Here, of course, p is merely the magnitude of the vector $\mathbf{p}$, and the resulting expression is not inconsistent with the assumption that pressure has direction.

4. The proposition as to whether the pressure field within a static fluid is a vector field or a scalar field, may, perhaps, best be dealt with by remembering that, as far as the observation and measurement of fluid pressures are concerned, it is always a matter of the *resultant* fluid pressure. If resultant pressures only are considered in characterizing a pressure field, it becomes evident that this field is *zero* at points *within* a static perfect fluid (since, otherwise, translational motion, in the macroscopic sense, would occur and the fluid would no longer be "static"), and that the meaning of the law stated by the equation,

$$p=p_0+\int \rho g dh,$$

(where p_0 is the value of p at the point of reference, ρ is the density, g is the acceleration of gravity, and h is the distance from the level surface through the reference point) in the statics of perfect fluids is that this gives the magnitude of the resultant pressure which would be exerted on any rigid surface that might be passed through a point in the fluid. If no surface passes through this point, the resultant pressure, as has been said, must be zero. If such a surface does pass through the point, the resultant pressure has the magnitude given by the above expression and a direction normal to the surface.

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[1] R. D. Summers, *Am. J. Physics* **14**, 311 (1946); **17**, 319 (1949). Vola P. Barton, *Am. J. Physics* **17**, 318 (1949).

Experiments for the Elementary Laboratory

I AM doing some research to discover what makes an effective and economical program of experiments for the laboratory phase of a first-year college physics course. Perhaps your readers can aid me with some references.

My evidence to date seems to show that the following logic will lead to an effective series of experiments:

> For teaching physical facts and phenomena, demonstrations are as effective as individual students' experiments.
>
> There are certain abilities individual experiments help develop in students which demonstrations cannot, among them being: (1) ability to use laboratory tools, apparatus and instruments; e.g., micrometer, camera; (2) ability to take significant data and analyze them most meaningfully; e.g., averaging by the method of differences, discovering the relationship between variables with graphs.
>
> Therefore, experiments should be chosen to give the students an opportunity to learn the use of apparatus and analytical techniques. If the series of experiments thus selected omits certain important phenomena, teach these with demonstrations.

The first step, then, in selecting experiments would be to make a list of the tools and instruments students should learn to use and another list of the techniques for taking and analyzing data in which they should become proficient.

Despite the fact that reputable teachers and teachers' organizations have stated such principles, I have been able to locate no research which has investigated and named the specific abilities that are desirable and practical.

An arbitrary list of my own would be as limited as my background. Could your readers refer me to articles, in your journal or any other, which discuss this question?

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Modernizing the Constitution and By-Laws

TWO years ago President Buchta appointed a committee to study the basic documents of the Association and propose such amendments as might be needed to meet criticisms of the current text and to adjust the structure of the Association to our present size and activities. This committee, composed of B. H. Dickinson, R. L. Edwards, P. H. Kirkpatrick, P. E. Klopsteg, C. J. Overbeck, and D. Roller, studied the constitution intently in the light of past and current practices and the recommendations of various committees and interested individuals.

Although it was the resolve of the committee to alter nothing for the pure pleasure of making changes the result of their labors is practically a new text. Scores of criticisms were deliberated and in most instances it was considered advisable to discard old versions and start over rather than to polish old phrases. The new version as accepted by the executive committee has been mailed to the membership, not for approval but for study and criticism. The committee hopes in this way to receive guidance that will enable it to bring out within a few weeks a superior text of assured adequacy and acceptability.

It is the purpose of this note to indicate the principal points of difference between the version which is now on the desks of the members and the one officially in force. Most of these differences are matters of form. Grammar and spelling were improved, many passages which had been found ambiguous were reformulated with precision, and the logical structure of the documents was modified by removing from each article matters not relevant to the title, and by assembling relevant matters from wherever found. For example, the definition of emeritus membership has been transferred from the by-laws to the article of the constitution which is titled "Membership." This article is relieved of a discussion of the procedure to be followed in electing honorary members, and this discussion, with verbal changes, has been incorporated in *Article IV. Election to Membership*. Other innovations not likely to be contested are the extension of voting privileges to honorary and emeritus members, the creation of a mechanism for electing emeritus members, the extension of this status to nonteacher members, introduction of accurate definitions of the terms of officers, and the legalization of a few practices, long current, such as admission of members without executive committee vote and authorization by the president of minor expenditures not explicitly covered by the budget.

The term "regular member" is proposed for that class of membership previously designated by the word "member," a term which has been found too generic for application to a subclass within the membership. Current dues figures are included in the appropriate by-law, and the *American Journal of Physics* is recognized by name. The statement of the objects of the Association has been reworked and the method of amending the by-laws has been clarified and slightly liberalized.

A substantial innovation is the proposed government of the Association by a council whose powers are to be exercised, in the interim between meetings, by a smaller body to be known as the executive committee. There is a possibility of confusion here, inasmuch as the body now called the council is approximately the executive committee of our past and present practice. The change has been advocated on the grounds that in recent years the executive committee, enlarged by a growing complement of regional members, has been found unwieldy and not apt to render prompt and informed decisions when deliberations must be conducted by mail. The proposed executive committee, including all members of the council except the representatives of regional sections, would have a membership of ten, a majority of whom would almost certainly have a background of Association experience fitting them for independent consideration of Association business. This slight concentration of power has been criticized as antidemocratic, but it follows the practice which has been found necessary in the American Institute of Physics and many another scientific organization of growing membership and increasingly complex functions.

Following the lead of the committee on election procedures we have proposed automatic succession of the vice president to the presidency after one year of office. Such succession is actually an old custom of the Association, carried on by repeatedly electing the vice president to the presidency in competitive election. The defect of this system has been the useless felling of good presidential timber in a contest where only one of two qualified candidates may be utilized.

It is not a purpose of this note to argue for the new drafts but to expose their nature to the wisdom of the electorate. The chairman of the committee on constitution and by-laws will still welcome correspondence tending toward the betterment of our fundamental documents.

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The Fitting of a Straight Line by the Method of Grouping

SINCE the least-squares method of fitting a straight line to a set of observations is time-consuming and rather involved, it is often desirable to use a simpler method for ordinary routine work. This is especially true in the undergraduate laboratory. One such method, in which the observations are divided into two equal groups, has been discussed by Gaehr[1] and by Cooksey.[2]

This method is a particular case of a method of grouping discussed by Jeffreys.[3] If we group the first m observations (x_i, y_i), and the last m observations (x_j, y_j), of the complete set of n observations, then the value

$$b' = (\Sigma_m y_j - \Sigma_m y_i)/(\Sigma_m x_j - \Sigma_m x_i) \tag{1}$$

will be an estimate of the slope of the line of best fit. In the method advocated by Gaehr, m is chosen to be $n/2$; i.e., all the observations are used. This, however, is not the best value of m, as we shall now show.

Suppose for convenience that the origin of the variable x is chosen so that $\Sigma_n x = 0$. Then, if b is the value obtained by the method of least squares, the standard error $\sigma(b)$ is given by

$$\sigma^2(b) = \sigma^2/\Sigma_n x^2,$$

where σ is the standard error of an observation. Also

$$\sigma^2(b') = \sigma^2 2m/(\Sigma_m x_j - \Sigma_m x_i)^2.$$

The ratio $\sigma^2(b)/\sigma^2(b')$ is called the efficiency η of the method. The best method of grouping will be that for which the efficiency is a maximum.

If the observations are roughly equispaced, at intervals t say, then

$$\Sigma_n x^2 \approx t^2 n^3/12,$$
$$(\Sigma_m x_j - \Sigma_m x_i)^2 \approx t^2 m^2 (n-m)^2,$$

and

$$\eta \approx 6(m/n)(1-m/n)^2.$$

This has the maximum value 8/9 for $m = n/3$. For the case discussed by Gaehr, $m/n = \frac{1}{2}$ and the efficiency is $\frac{3}{4}$, as was proved by Cooksey.

Thus the best estimate of the slope is obtained by grouping the observations into three approximately equal groups and using the means of the first and third groups, a result apparently due to Eddington.[3]

By writing $(b - b')$ as an explicit function of the observations, it can be shown that

$$\sigma^2(b-b') = \sigma^2(b)\{(1/\eta) - 1\}.$$

Hence it is very unlikely that b' will differ from b by more than the standard error of b.

If Σv^2 denotes the sum of the squares of the residuals using the value b, and $\Sigma v'^2$ the sum using the value b', it is easy to prove that

$$\Sigma v'^2 - \Sigma v^2 = (b-b')^2 \Sigma x^2.$$

If $s^2 = \Sigma v^2/(n-2)$ and $s'^2 = \Sigma v'^2/(n-2)$, it is found that the expectation of $s'^2 - s^2$ is very much smaller than the standard error of s^2. Therefore s' will be a close approximation to s, and hence a correspondingly good estimate of σ.

The explicit equation for the straight line in terms of the original variable x is

$$(y - \bar{y}) = b'(x - \bar{x}),$$

where $\bar{y} = \Sigma_n y/n$, $\bar{x} = \Sigma_n x/n$, and b' is given by Eq. (1) with $m \approx n/3$.

The estimated standard error of b' is

$$s(b')=(2m)^{\frac{1}{2}}\{1/(\Sigma_m x_j-\Sigma_m x_i)\}s',$$

and the estimated standard error of the fitted value $y(x)$ is

$$s(y)=\{(s'^2/n)+(x-\bar{x})^2 s^2(b')\}^{\frac{1}{2}}.$$

If $r'=0.6745s'$ is substituted for s' in the above formulas, the corresponding probable errors are obtained. In addition, r' may be obtained by means of Peters' formula.

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[1] P. F. Gaehr, *Am. J. Physics* **15**, 430 (1947); **16**, 359 (1948).
[2] C. D. Cooksey, *Am. J. Physics* **16**, 189 (1948).
[3] Jeffreys, *Theory of probability* (Oxford, ed. 2), p. 193.

AMERICAN JOURNAL OF PHYSICS VOLUME 18, NUMBER 5 MAY, 1950

ANNOUNCEMENTS AND NEWS

Book Reviews

Crystals and X-Rays. Kathleen Lonsdale. Pp. 199, $8\frac{1}{2}\times5\frac{1}{2}$ in. D. Van Nostrand Company, Inc., New York, 1949. Price $3.75.

This justly celebrated research authority has written a small and very compact book of remarkable value to students of physics and chemistry alike. The variety and scope of the intensely interesting material covered and the clarity, directness, and vividly imaginative quality of its expository style set it apart as a unique and remarkable performance. The book is definitely not a popularization written for the lay public. As the author makes clear in her foreword, her aim is to introduce a complex and beautiful domain of science in a compact and therefore rapid way to science students wholly or partially unfamiliar with it. It is not a treatise nor a textbook but in the author's own words is intended to persuade the reader "to pass on from this book to textbooks which are much more thorough, precise and specialized." Quoting her again, "Many people who know a great deal about chemistry and physics and other subjects, however, do not fully realize the value of x-ray crystallography as a tool; not merely an industrial tool, but a tool by means of which other sciences may be better understood."

This reviewer has read every word in this book with intense interest and admiration. For more than twenty-five years, he has used x-rays extensively as a research tool to answer questions in atomic and nuclear physics and has had much to do with many of the topics covered by Kathleen Lonsdale's book (although he has never engaged in x-ray crystallography for its own sake). *Crystals and X-Rays* has revealed to him many new and valuable facets of this astonishingly beautiful and fruitful subject which he would otherwise have overlooked, and he feels sure that many another physicist of maturity could profit equally by reading it.

Many of us can readily recall the days when chemists and physicists felt it was unsafe to *think* (much less talk) of atoms, electrons, and nuclei as real entities. They were abstractions or mental concepts elaborated by the mind out of the raw material of reality. The real raw material consisted of "pointer readings" or "space-time coincidences" and atoms or electrons were abstractions to help us interpret this raw material. They still are abstractions, of course, but such extreme logical caution is no longer a fetish emphasized by scientists. There used to be a joke about the philosopher who called a physicist's attention to a shorn sheep and who was sternly reprimanded by the latter with the reply "yes, I see a sheep shorn on *this* side." Today this story might hardly be understood. In reading *Crystals and X-Rays* perhaps the most striking single impression this reviewer has received is the tremendous part that the research results described therein have played in this change of attitude as regards the reality of the atomic world; a world which has never been directly seen at all and yet for which the evidence is now so overwhelming that it stands almost on the same level of reality as the familiar objects of everyday life. Along with the Wilson cloud chamber, the Geiger counter, Aston's mass spectrograph, Stern's and Rabi's molecular beams and the revelations of high frequency spectra, one must accord the field of x-rays a very prominent place in this revolution.

Mrs. Lonsdale paints this fascinating picture with broad, uninhibited and vivid brush strokes, her one aim being, at every point, maximum clarity and conciseness. To quote a single example of this style, she says, "An investigation of the thermal expansion of the phthalocyanines, plate-like organic molecules which stack themselves together in the crystal in a zigzag way, has shown that the expansion is not only anistropic, but may even be negative in certain crystal directions, simply because the vibrating molecules can pack themselves more comfortably if they *turn* slightly, instead of merely taking up more room in all directions." The reader, like Alice, is thus led so easily and by such homely common sense analogies into this wonderland of atomic reality that he scarcely realizes what has happened to him—that imagination and reason combined with the scientific experimental method have permitted him to shrink, at least with the eyes of the mind, until he lives with and sees the atoms in their lattice work patterns vibrating as the waves of thermal motion ripple and cross over the atomic planes. More than half of the book is devoted to explaining with great clarity the methods used in the analysis of crystal structure and one receives a just impression of the tremendous amount of labor and ingenuity this subject involves, particularly as regards the reduction and interpretation of the data. There is a wealth of fine illustrations, both line drawings and half-tone reproductions, of diffraction patterns, Laue and powder

diagrams, rotating crystal spectra and the like, which help enormously to easy comprehension.

The style is not only lucid but witty. There are occasional and delightful flashes which reward the reader with a hearty laugh at the most unexpected places but I shall not spoil the enjoyment by quoting them here.

One serious criticism that, in this reviewer's opinion, can justly be aimed at this work, is the paucity of references to the original literature. All that is given is a list of books, uncorrelated with the text, covering a page and a half at the end. A few of the illustrations have accompanying references. Frequently, intensely interesting material is necessarily compressed into a single sentence and the reader is disappointed to find little or no clue to help him read further about it in journal articles or books. This is in complete disaccord with the stated object of the book. The author should not hesitate to introduce numbered footnote references to the original literature on every important topic she mentions. This would make the book worth its weight in gold. If she suffers from an aversion (not shared by this reviewer) to cluttering the foot of every page in this way, she could follow the excellent example of M. Siegbahn and place all the references at the end in order of date.

This reviewer has noticed a few minor slips. On p. 24, the numerical constant (hc/e) in the equation $\lambda_{\min}V_{\max}=1.234\times10^{-4}$ is now believed to have a value much nearer 1.239×10^{-4}.

An old and sturdy but indefensible misconception which seems very widespread among x-ray crystallographic people is repeated on p. 140 in the discussion of primary extinction. The reviewer believes this has taken root from the unfortunate practice of calling the quantity $\rho=E\omega/I$ a reflection coefficient when in fact it is an *angle*, a measure of the angular range over which Bragg reflection occurs. (The name "integrated reflection coefficient" seems more appropriate for this quantity.) In explaining how the reflections from a nearly ideally perfect crystal come to be much weaker than those from a more imperfect one, the author gives a correct and vivid picture of the strong interference effects from the multiple to-and-fro reflections between planes which rapidly extinguish the amplitude in the primary direction because of the change of phase of $\pi/2$ at each reflection and hence π after two or an even number of successive to-and-fro reflections "so that a twice reflected beam is opposite in phase to the incident primary beam and partially interferes with it. Both reflected and transmitted beams, in fact, are frittered away, as it were, by interference; so that after passing through some 10^4 crystal planes there is no primary beam left in the right direction for Bragg reflection, and the reflected beam is reduced not only by interference, but by the fact that the rest of the crystal, under the skin, cannot reflect a primary beam that does not reach it." [Quoted from p. 140.]

Now this reviewer believes the quoted statements are nonsense but he is also well aware that Mrs. Lonsdale here sins in very good company.

Studies with the two-crystal spectrometer have pretty well verified the correctness of the dynamical theory of x-ray reflection in perfect crystal lattices, first so ably worked out by C. G. Darwin. If we consider the ideal case of a highly monochromatic beam of, say, 0.7A x-ray incident on a "perfect" crystal at an angle defined with much sharper definition than the width of the diffraction pattern, then at the most favorable angle the crystal can reflect nearly *100 percent* of the beam. In this condition, the reason why the beam does not penetrate deeply into the crystal is because the interference effects described make the reflection so *efficient*, not because interference "fritters away" any intensity. (The interference of coherent wavelets cannot reduce the total energy in these wavelets! It merely redistributes this energy, extinguishing it in certain regions or directions and piling it up in others.) Only absorption processes which degrade the x-ray energy can fritter away the incident or reflected beams and precisely in the case of strong primary extinction in nearly ideal lattices absorption is reduced to a minimum because of the slight penetration. Thus, "frittering away" is here an incorrect term. If we disturb the surface mechanically or otherwise reduce the approach to ideal perfection of the lattice, the reflection (integrated over its entire angular range) is enhanced not by an increase in the peak reflection coefficient (which cannot exceed 100 percent!) but by reason of the increased angular range coming from the disorientation. Thus, it is misleading to say that "primary extinction gives weak reflections." A preferable statement would be that the approach to a very ideal lattice is accompanied with strong primary extinction and also results in Bragg reflections limited to very narrow angular ranges which place a severe limitation on the solid angle into which each excited atom in the x-ray tube target can radiate. Usually slit spectrometers of relatively low angular resolving power are used. Since the angular widths over which Bragg reflection occurs in very perfect crystals are of the order of a second or so of arc, the angle, and hence the power associated with the reflection, can easily be increased many factors of ten without any detectable change in the apparent width of the reflection unless really refined instruments such as the two-crystal spectrometer are used in the study. One cannot help wondering if it is not significant that there is nowhere any mention in Mrs. Lonsdale's book of the two-crystal instrument.

Another surprising omission is the almost complete absence of any discussion of the Compton effect and of modified or incoherent scattering. In the reviewer's opinion this, bearing as it does directly on the particle-wave duality, is by far the most far-reaching and significant thing that has come out of x-ray research. However, in fairness we must recall that Mrs. Lonsdale has put the word "crystals" first in her title.

The reviewer is entirely in sympathy with the general conciseness and brevity which makes the book so suitable to its stated purposes. Nevertheless, he feels that at a few points one or two extra clarifying sentences would have been real improvements. A perhaps trivial example is on p. 13 in Fig. 5 and the accompanying discussion in which one learns that "a divergent incident beam gives a convergent diffracted beam" and it is stated that this "could be quite simply explained if the slightly divergent primary

beam was being reflected from some kind of planes in the crystal." The neophyte would be considerably confused by these words and by the picture for he would recall that the laws of image formation and of reflection by plane mirrors call for a *divergent* reflected beam if the incident beam is divergent. It would have greatly clarified this to have added a word of explanation in a footnote to the effect that the planes are frequently distorted so that their directions are somewhat ill-defined and that the dominant influence here is not the specular reflection law (requiring equal glancing angles of incidence and reflection with the plane) but the Bragg law coming from the periodicity normal to the planes which imposes still more imperatively that the angle of deviation of the beam shall *be constant.*

Again on p. 32 the well-known modified equation

$$n\lambda_0 = 2d(1-\delta/\sin^2\theta)\sin\theta,$$

containing the factor correcting for the effect of refraction is stated without pointing out that in this form it is valid for only one special case, that of Bragg reflection by planes parallel to the boundary surface of the crystal which must also be the common surface of entry and of exit of the beam. This equation as it stands is quite inapplicable to the more general cases of Laue reflection.

It would be wrong to fail to point out the above criticisms but the reviewer realizes that, by so doing, these very minor blemishes on an outstandingly excellent work are unduly magnified. They are, as a matter of fact, fairly typical errors in works on x-ray crystallography that have been propagated now for many years from book to book and should be corrected. Mrs. Lonsdale's work is so outstandingly excellent in most respects that their repetition can surely be forgiven.

Jesse W. M. DuMond
California Institute of Technology

Albert Einstein: His Work and Its Influence On Our World. Leopold Infeld. Pp. 125. Charles Scribner's Sons, New York, 1950. Price $2.00.

In this modest volume Professor Infeld gives a popular account of relativity theory, and of the other scientific achievements of Albert Einstein. By virtue of his own contributions to relativity theory, his associations with Einstein, and his past literary work, the author is well qualified for this task. The story he tells is one, to be sure, that by now has been told many times, and on many different levels of scientific sophistication; but the permanence and depth of Einstein's work and the appeal of his devoted life are valid themes that bear much retelling and rereading.

After some introductory remarks the author arranges his book into four chapters: The First Einstein Revolution gives the development of the special theory of relativity; The Second Einstein Revolution is concerned with the general theory and its applications in cosmology; in The Unfinished Revolution Einstein's work in the quantum theory of light and in Brownian motion is discussed; and the final chapter, Beyond the Revolutions, is devoted to attempts toward a unified field theory and to other than scientific activities of Einstein. The treatment is everywhere nonmathematical, and no previous knowledge of physics is assumed; but, as seems to be characteristic of many of the best popular science expositions, previous scientific knowledge does help the reader. Only the thoroughly versed relativity theorist, I should think, would be bored with Professor Infeld's discussions of the theory.

There is one particular in which the author's presentation, it seems to me, could be misleading. In discussing the Lorentz transformation he uses Fifth Avenue as one coordinate system, and a moving bus on the avenue as another. The bus driver finds his clock to have a slower rhythm, because he is in a moving system, than do the clocks along Fifth Avenue. The paradox of the twins is then introduced, a twin in the bus being taken as the one becoming younger than his brother. The reader may be confused at this point, since the equivalence of coordinate systems in relative motion to each other has been stressed, and yet in the illustration the Fifth Avenue coordinate system is taken as an "absolute" one by which the bus driver determines his motion. Actually we might expect that the bus driver would find his clock to be normal, but the "moving" Fifth Avenue clocks to decrease in tempo.

The title of this volume refers to Einstein's influence as well as to his work. Professor Infeld does give some indication of the many effects that have come from Einstein's work, but he gives no systematic treatment, in the manner of a cultural historian or critic. (The reader interested in Einstein's influence, scientific and philosophical, can do no better than look to the remarkable volume, *Einstein: Philosopher-Scientist*, recently published in the Library of Living Philosophers series.) However, the author's personal familiarity with Einstein gives the book a warm touch that recommends it. In communicating to the reader something of the personality of Einstein, Professor Infeld also gives us some feeling of how fortunate all scientists are that Einstein is today to the generality of mankind the symbol of science.

Richard Schlegel
Michigan State College

Science and Civilization. Robert C. Stauffer, Editor. Pp. 212+xiii, $5\frac{1}{4}\times 8\frac{1}{2}$ in. University of Wisconsin Press, Madison, 1949. Price $2.50.

This volume is a compilation of eight addresses delivered at a symposium in 1949 under the sponsorship of the Wisconsin History of Science Group, in celebration of the One Hundredth Anniversary of the founding of the University of Wisconsin.

The titles of these addresses and their authors are listed in order, with brief comments.

Aristotle and the Origins of Science in the West. Richard P. McKeon.—In this very learned discussion of the philosophy of Aristotle, the author concludes that the contribution of Aristotle to the origins of science in the West must be stated on three levels:

A. Aristotle discovered facts and constructed theories that had profound influence on later scientists.

B. His terms and ideas, his deductions and theories

are influential in a derived way in later investigations and discoveries.

C. His philosophic generalizations force one to realize that progress in science is achieved not merely by meticulous observations and measurement or by the elaboration of theories, but also by substitution of theories which interpret facts differently, and by the comparison of schemes of explanation.

Some Unfamiliar Aspects of Medieval Science. LYNN THORNDIKE.—The author shows how difficult it is to draw correct conclusions concerning the early development of science, because our knowledge of the past frequently comes to us as the result of what is often an accidental survival of a single manuscript and that often incomplete.

This means that any new discovery of a single ancient manuscript may revolutionize our historic generalizations relative to a given era. He finds much that is commendable in the less familiar writings of the savants of the eighth to the twelfth centuries which lead to the larger and more rapid development of the roots of science in the thirteenth century.

The Definition of Scientific Method. MAX BLACK.—The author's thesis is that since the term Science has no definite and unambiguous application, it is impossible to define "scientific method" because of lack of definite criteria. After a very clear exposition of the difficulties involved he proposes "that we treat scientific method as a historical expression meaning among other things, those procedures which as a matter of historic fact, have proved most fruitful in the acquisition of systematic and comprehensive knowledge."

The Meaning of Reduction in the Natural Sciences. ERNEST NAGEL.—The author points out that the history of the development of science offers many illustrations of how one science, by the normal expansion of its body of theory, when properly specialized may be made to include, as a special case, another science, and thus to reduce the latter science to a somewhat secondary state of importance in the integration of knowledge. He seeks to answer the question, what are the essential requirements for the reduction of one science to another, and concludes that the reducibility or irreducibility of any science is not an absolute characteristic of that science.

Physics as a Cultural Force. PHILIP E. LE CORBEILLER.—With conscious reference to the Harvard Course in General Education, the author discusses the question—what has physics to offer over and beyond the knowledge of physical laws, that is a contribution to the common culture? He assumes as a working definition that culture is the opposite of specialization, and concludes that a student (freshman or adult) having had some part of his proposed program, might be expected to have a better grasp of the facts underlying economic, social, and political questions of the day, the techniques of production and distribution, the legislation of transport and power, patent law and many other such problems of economic and legal import, and more important still, the student should gain an understanding of the conditions of life of the industrial worker.

The reviewer cannot help but remark that these important goals are ambitious, and indeed, are more difficult of attainment than the imparting of a technical knowledge of physics.

Science as a Social Influence. FARRINGTON DANIELS.—The author presents a short but delightfully written paper discussing the subject under five headings:

A. The benefits which society derives from science.

B. The distinction between fundamental research and applied research.

C. The responsibility of society for the development of science.

D. The responsibility of the scientist to society.

E. The scientists' obligation to find new sources of raw material and energy.

Foreseeing the rapid depletion of the world's obvious sources of available energy, the author suggests that society should look to atomic power—to the only atomic pile that man can trust his fellow man to use, because it is so far away, the Sun—for the energy of the future. He advocates intensive research in photosynthesis in order to provide the necessary energy which might give the human race hope of continuing its life on earth.

Metaphors of Human Biology. OWSEI TEMKIN.—The author cites many examples of the comparison of the human organism, to a society, or a state, to a machine, to a factory, and seeks to inquire into the reason for this scientifically dangerous habit of reasoning by analogy in the biological field. He concludes, that for the early biologists, these metaphors were not figures of speech only, but were integrating concepts used by them in directing their thinking. He defends this type of reasoning by the argument that the use of metaphor in human biology is not an aberration from which even great men have failed to escape, but by so doing they shaped concepts of human biology which conformed to their own ideas and with the thoughts and feeling of their times.

Science and Society. WILLIAM F. OGBURN.—While a science of society is much to be desired, the author points out the obstacles to the development of a science in the social field, which will require much time, and when complete, its accomplishments must be limited because of the many variables in human mass behavior.

In this well-written article the author is in no way pessimistic as to the future of sociology, but he cautiously points out that complete knowledge of society, if and when it is ever available, cannot solve all social problems until such complete knowledge is used with wisdom and understanding. Selfishness, love of power, emotional bias, as well as many other variables remain as obstacles to a perfect social structure.

The Wisconsin History of Science Group is to be congratulated on their sponsorship of the symposium that resulted in this collection of scholarly papers which, except for this occasion, might never have been written. The diversity of the training and professional interests of the various authors, as well as their prominence in their chosen fields would guarantee a diversity in their approach to any problem. One cannot complain of a lack of inte-

gration of the various topics discussed, when it is remembered that there remains yet more to be said of the relation of science to civilization. The binding together of these papers into a single volume is an invitation, to all who will, to further discuss this inexhaustible subject.

WILLIAM S. WEBB
University of Kentucky

Matrix Analysis of Electric Networks. P. LE CORBEILLER. Pp. 112. Harvard University Press, Cambridge; John Wiley and Sons, Inc., New York, 1950. Price $3.00.

This book is the first of a series of monographs in applied science written by members of the staff of Harvard University. The aim is to present material of advanced nature in such a form as to be both concise and complete in itself.

In this volume a portion of a general theory developed by Gabriel Kron is applied to the analysis of stationary electric networks. Methods dependent upon the use of matrix algebra are used to determine unknown currents and voltages in such systems. The heart of the treatment lies in special properties of a matrix relating individual currents in all branches of the network with the circulating mesh currents introduced in the method of Maxwell. Through the use of this special matrix it is possible to reduce the solution of relatively complex systems to a straightforward automatic process.

As is the case with many powerful techniques, the procedure which one must follow in applying this method to a simple situation is likely to seem unnecessarily complicated. Fortunately, the circuits with which most of us have to deal are usually simple. If such is not the case, we are inclined to make various approximations until they have become sufficiently simple for analysis by the customary methods. For such circuits, there is probably no reason to use the type of analysis described here. On the other hand, if one is faced with a network of considerable complexity this method offers assurance of a solution through a step-by-step process not hard to follow. Circuits with all sorts of couplings, even asymmetric in nature, and having generators of various kinds connected in any manner, can be handled by the same procedure.

The book is a fine example of the lucid style in which Professor Le Corbeiller is able to present a difficult subject so that it seems easy to the student. After a brief introduction to matrix algebra, the discussion of the Kron method is begun. It is applied to circuits with the analysis based upon first the mesh method, then the node method, and finally a combination of the two. Beautifully simple proofs are given for the basic relations of the process. Numerous exercises for the reader are scattered along the text.

The book is recommended for all those who may have to deal with electric networks of considerable complexity.

W. J. CUNNINGHAM
Yale University

Constructive Uses of Atomic Energy. Edited by S. C. ROTHMAN. Pp. 258, Figs. 38, $5\frac{1}{2}\times8\frac{1}{2}$ in. Harper and Brothers, New York, 1949. Price $3.00.

Beginning with the first chapter by Arthur H. Compton, in which the broad aspects of atomic energy and its relation to man are described, through to the very helpful glossary of terms and the bibliography, this book comes as a breeze of fresh air in the midst of talk of bombs and superbombs.

Man's new responsibility, as a result of his new knowledge on how to destroy, is beautifully pictured by what Dr. Compton says: "When our first parents ate the fruit of the tree of knowledge, they became as gods, knowing good from evil. Much as they longed to return to the garden of innocence, an angel with a fiery sword stood in their way. Their only hope for peace lay in work to make the earth give them a fuller life . . . they . . . shared the task of their Creator and came to be called His children. The same angel with the same fiery sword prevents us from returning to a pre-atomic age. We have no choice but to use our great new powers in the effort to build a better world"—or be annihilated by the consequences of our new knowledge.

The second chapter gives the background on The World Within the Atom, by L. W. Chubb. It is clear-cut and particularly well illustrated. The third chapter reflects the feelings of many scientists in 1946, hoping for a settled, peaceful world, so that reconversion from military thoughts and purposes could progress faster along some important lines of research, such as that involving radioactive carbon, which is discussed in detail. The fourth chapter, by M. Blau and J. R. Carlin, should appeal particularly to electrical engineers, because it shows how radioactive isotopes can be applied to the production of ionized gases, visible light, and many problems of instrumentation and control.

H. Etherington gives a very good review of information available to the public on the engineering aspects of nuclear reactors. It has the logical and practical approach characteristic of the best engineering practice, and shows the great need of continued research to solve the many technical problems still ahead of us, if we are to take advantage of atomic power in industry.

The application of atomic energy to the propulsion of airplanes is beautifully described from the point of view of the broad engineering concepts by Andrew Kalitinsky in Chapter 8. No more daring venture than this can be found in any of man's activities. Even the first circumnavigation of the globe cannot have given the participants as much to overcome and risk as this project of making possible continuous circumnavigation in a matter of one or two days.

The great versatility of a long list of newly available radioactive nuclei is well illustrated in Chapters 6, 7, 10, 11, 12, 13, and 14. The convenience of being able to detect individual pulses of energy from specific disintegrations multiplies the many old approaches for detecting, tracing, measuring, and controlling variables in our industry. Rather than ask what might possibly be done to accomplish a certain purpose, it is now practical to specify what

is the best that one wishes to do. Once a problem is analyzed into its simple components, one may now expect to find a technique that will satisfy all the requirements specified.

While all of us are very anxious to have industrial, agricultural, and other economic advantages from the new advances in *Constructive Uses of Atomic Energy*, it is the application to medicine, as described by C. P. Rhoads, John E. Christian, and G. Failla, that make all of us feel particularly thankful. Increasing the maturity in our population, by increasing life expectancy, while guided by the aggressive spirit of youth, with the certain knowledge that the struggle for growth and advancement must continue, can and will improve our world for happy, healthy human life immeasurably.

An idea of the intensive development of materials of construction required for these new fields of endeavor is given in Chapter 9 on Ceramics and Nucleonics by A. L. Johnson. One should read this chapter with the realization that similar broad, basic research and development has been required for each of the various materials of construction.

I know of no single source of scientific inspiration and guidance to the growing youth of our nation that can mean as much as this little book. It should give them both a broad, philosophical approach, as well as information on detailed engineering applications to stimulate their thinking and make them realize that twentieth century progress is just emerging into new life and growth.

JOHN J. GREBE
Dow Chemical Company

The Crystalline State, Vol. I. SIR LAWRENCE BRAGG. Third Impression. Pp. 352. G. Bell and Sons, Ltd., London, 1949. Price $8.50.

When Vol. I was first written in 1933 the author had intended to give in it a survey of the whole subject which would form an introduction to succeeding volumes. The treatment of the main principles of the then-new subject, its achievements up to that time and possible future applications, however, made that volume complete in itself. As a result it has been widely used as a textbook and a reference book. While no new material has been added in the third impression, the wealth of basic information contained in it and an excellent presentation of each topic are still worth pointing out. Usually a writer in the field of x-rays and crystal structure starts with a historical introduction, and the production and properties of x-rays, since these topics present a fascinating story of the discovery and the early development of the subject. This author relegates these topics to the last chapter and the appendixes in the book and starts the first chapter with the main theme, the factors that characterize the crystalline state. At the very outset the reader is introduced to the crystal pattern, lattice planes, crystal axes, the law of rational indices, crystal zones, symmetry, etc. This is followed by the concept of diffraction by the crystal lattice, the condition for a diffracted beam, the difference between optical diffraction by the line grating and diffraction by the three-dimensional crystal grating. The experimental methods and typical examples of crystal analyses to which the author has contributed abundantly are presented in the next two chapters. The chapters on The Principles of Structure Analysis, Chemical and Physical Crystallography, Crystal Texture, and X-ray Optics cover basic principles of each topic. Examples and illustrations, in general, are based on original work, for which adequate references are given. Since the first publication of this volume the field of each topic has expanded and one finds such books as *X-ray Diffraction in Crystals* by W. H. Zachariasen, *X-ray Crystallography* by M. J. Buerger, *Chemical Crystallography* by C. W. Bunn, *Structure of Metals—Crystallographic Methods* by C. S. Barrett, *Fourier Technique in X-ray Organic Structure Analysis* by A. D. Booth and several others that cover the individual fields much more fully; yet the reader can still go back to this volume for much basic information which is hardly out-of-date.

In Chapter 10 on Applications of X-ray Methods to Problems of Pure and Applied Science, some excellent illustrations of the application of the method to chemical composition, the structure of alloys, identification of the constituents of the crystalline matter and coefficients of thermal expansions are given. Each application emphasizes the uniqueness of the x-ray diffraction method.

The diffraction of electrons by crystalline and amorphous materials was a relatively new field in 1933, yet the author's treatment of this subject, including the wave mechanics of electrons, the equipment and the techniques employed, the atomic scattering factor for electron waves and diffraction of electrons by powdered materials, single crystals, and gas molecules was quite comprehensive. The reader today will still find it an excellent review of the subject.

While the second volume of this book is already in print and the third volume may follow soon the reader will find it worth his while to go over the first volume to acquire basic information, and establish the continuity and growth of the entire field. There is much in this volume that warranted its third impression and which recommends itself to a critical reader.

S. S. SIDHU
University of Pittsburgh

From Euclid to Eddington. A Study of Conceptions of the External World. SIR EDMUND WHITTAKER, F.R.S. Pp. ix+212. Cambridge University Press, London, 1949. Price $3.75.

Whittaker has given us in this slim volume a very complete history of the fundamental concepts forming the foundation of physical theory. Such a presentation is all the more meritorious as it requires of the author a mastery of all the historical stages of physics as well as knowledge and understanding of current theories, hypotheses, and mere speculations. Whittaker combines this background with a facility of expression which makes many of his

formulations and explanations considerably more lucid than those of the original proponents of certain theories.

The book is divided into five parts. Part I, entitled Space, Time, and Movement, carries the development of geometry and kinematics from classical Greek concepts through to the special theory of relativity. By combining a history of "pure" geometry with that of epistemology (as it affects the relationship between "mathematical" and "physical" spaces) and of physical kinematics proper, Whittaker has succeeded in tracing the interrelationship between all these developments in a manner that the reviewer does not remember having seen elsewhere. Part II, the Concepts of Classical Physics, discusses not only the unification of physics effected by Newtonian mechanics (supplemented by the kinetic theory of heat), but goes on to discuss the specific problems raised by the emergence of Maxwell's theory of the electromagnetic field. Whittaker discusses very carefully the aether problem as well as the problem of the localization of energy in mechanics and in a field theory. Again, the discussion is carried forward to include the contributions of the special theory of relativity.

In Part III, dealing with the General Theory of Relativity, Whittaker covers about the usual material, but gives an account of the cosmological term which, in the reviewer's opinion, disregards some important opinions on this subject, including Einstein's own. The account of "unified" field theories covers the theories of "distant parallelism" very well, mentions Weyl's gauge-invariant theory, but completely omits all the five-dimensional and projective theories. Furthermore, and this omission is possibly most serious, Whittaker has apparently overlooked completely the unification of the field equations and the force laws, discovered in 1937 by Einstein, Infeld, and Hoffmann, and since brought to a high state of perfection. This development, which does not lead beyond the framework of Einstein's original (1916) theory of gravitation, is probably the most significant contribution made to the whole concept of field theories in the past twenty years.

Part IV deals with quantum mechanics. While the exposition of the foundations of quantum mechanics is excellent, the reviewer found the discussion of "the paradox of disentangled systems" (Einstein and Rosen *et al.*, 1935) glib and hardly satisfying. This paradox was developed as the starting point for a fundamental critique of the epistemological foundations of quantum mechanics. To show there is no *logical* inconsistency is to miss the point of the discussion, since nobody claimed there was.

Part V is entitled The Eddingtonian Universe. Having attempted, many years ago, to read Eddington's own formulation of his theories and having been totally unsuccessful, this reviewer was pleasantly surprised by Whittaker's lucid presentation. If for no other reason, the reviewer would recommend Whittaker's book warmly as the only known key to Eddington's mysteries. In particular, Eddington managed to convey to most of his readers the impression that he was trying to construct physical theories from purely logical principles and without recourse to any empirical facts. Whittaker sets the record straight by pointing out that Eddington does, in fact, borrow a number of *qualitative* concepts from contemporary physics, including relativity (equality of mass and energy, etc.) and quantum mechanics (Pauli's exclusion principle, for instance). What Eddington attempted to do was to construct from these general assumptions quantitative predictions, such as the total number of particles in the universe, the value of the fine structure constant, etc.

Whittaker's presentation requires of the reader some familiarity with philosophical principles and with modern mathematical concepts. Given these prerequisites, the reader will enjoy this book as a personal credo of scientific convictions by an unusually cultured mind. Even though one would hardly agree with every one of Whittaker's opinions (and he would probably be the first to disclaim any attempt at proselytizing in controversial matters), one can hardly fail to be impressed and stimulated by Whittaker's attempt to integrate all the contributions of the exact sciences and modern mathematics to our understanding of the physical universe.

PETER G. BERGMANN
Syracuse University

White rats have further confirmed the folly of summer sessions in colleges at lower latitudes unless the students be air-conditioned. . . .

The rats' memory, or retention of learning, was tested by bringing them back to the maze after a month's absence. Those from the 55°F room showed perfect retention of their previous learning, those from the 75°F warmth had to relearn about half, but those from the 90°F heat seemed to retain no memory of their former efforts.—CLARENCE A. MILLS, "Temperature Dominance over Human Life," *Science* **110**, 267 (1949).

Proceedings of the American Association of Physics Teachers

The New York Meeting, February 2–3–4, 1950

THE nineteenth annual meeting of the American Association of Physics Teachers was held at Barnard College and Columbia University, New York, on February 2–4, 1950. VICE-PRESIDENT ROLLER was chairman of the program committee for the meeting. Local arrangements were in charge of HENRY A. BOORSE and MARK W. ZEMANSKY.

A joint dinner with the American Physical Society was held on Friday evening, February 3, in the Grand Ballroom of the Hotel New Yorker. The after-dinner address was by FREDERICK SEITZ, University of Illinois, on the subject, "Physicists in the Cold War."

Invited Papers and Reports

Papers and Special Events

Development of social physics. JOHN Q. STEWART, *Princeton University.*

Presentation of the Oersted Medal of the American Association of Physics Teachers to Professor Orrin Harold Smith. PAUL KIRKPATRICK, *Chairman of the Committee on Awards,* and J. W. BUCHTA, *President of the Association.*

Experience plus realization. ORRIN HAROLD SMITH, *De Pauw University.*

Landmarks in the theory of magnetism—ninth Richtmyer Memorial Lecture of the American Association of Physics Teachers. J. H. VAN VLECK, *Harvard University.*

Joint Session with the American Physical Society

Can physics serve two masters?—address of the retiring President of the American Physical Society. F. W. LOOMIS, *University of Illinois.*

Panel Discussion: Methods of Developing Better Relations Between College Physics Departments and Secondary Schools

Methods of developing better relations with the schools. JAMES G. HARLOW, *University of Oklahoma.*

Stimulating interest in physics in secondary schools: the work of the California Section of the Association. DAVID L. SOLTAU, *University of Redlands.*

Summer courses for secondary school teachers; the General Electric science fellows at Union College. HAROLD E. WAY, *Union College.*

Panel Discussion: Methods of Training College Teachers of Physics

What kind of teachers do the liberal arts colleges need? HARRY J. CARMAN, *Columbia University.*

The training of college physics teachers in the graduate schools. CLAUDE E. BUXTON, *Yale University.*

The training program in the physics department of Pennsylvania State College. HAROLD K. SCHILLING, *Pennsylvania State College.*

Current trends in the training of college teachers. BERNARD B. WATSON, *U. S. Office of Education.*

Symposium: Use of Historical Material in Elementary and Advanced Instruction

A sense of history. I. BERNARD COHEN, *Harvard University.*

Kepler and the theory of the rainbow, CARL B. BOYER, *Brooklyn College.*

The caloric theory of heat. S. C. BROWN, *Massachusetts Institute of Technology.*

Do students find history interesting in physical science courses? CLEMENT L. HENSHAW, *Colgate University.*

Committee Report

Modernizing the constitution of the Association. PAUL KIRKPATRICK, *Chairman of the Committee on the Constitution and By-laws.*

Motion Pictures

Atomic physics. A 90-minute instructional sound film produced by J. ARTHUR RANK and shown by courtesy of the Atomic Energy Commission.

Leslie's cube, Tyndall apparatus, waves in string, glass and rubber rods, electroscope, electrolysis. Six three-minute sound films for elementary instruction shown by courtesy of the McGraw-Hill Book Company.

Contributed Papers, with Abstracts

Two sessions were devoted to the following contributed papers:

1. Acoustics: a neglected undergraduate subject. ROBERT H. RANDALL, *The City College of New York.*—Acoustics—more usually known as "sound"—has long been considered a necessary ingredient in every first-year college physics course. Rarely taken seriously as basic physics, the subject is, in general, included firstly, because it is traditional to do so; secondly, because it is a convenient way of approaching the subject of wave motion, the concepts of which are to be used, however, in connection with electromagnetic waves; and finally, because the nature of the subject lends itself to entertaining demonstrations. Upon the completion of elementary physics, the student rarely hears again of acoustics in the undergraduate curriculum. Even on the graduate level, many colleges offer no courses at all in this field. It is the contention of the author that no other branch of basic physics gives as

clear and as varied insight into the nature and the techniques of advanced physics. A methodical analysis of mechanical vibrations and of mechanical wave motion is the best introduction to radiation phenomena. The subject illustrates beautifully the important difficulty of fitting mathematics to physical boundary conditions. Nearly all branches of pure physics and many applied fields are illustrated and utilized in acoustics. In addition, student interest is intrinsically high without cajoling.

2. Adaptation of war surplus equipment to laboratory use. Frank P. Goeder and Louis R. Weber, *Colorado A. & M. College*.—During the past few years much war surplus equipment has been accumulating in halls, corners, and basements. As rapidly as possible, we have classified this material so that it could be found readily and used in our teaching and research program. The purpose of this paper it to point out some adaptations which have enhanced the work of our department. Some of the conversions and uses described were: (1) an accurate spectograph slit constructed from a gyroscope part; (2) a densitometer built from bombsight parts; (3) one of the pump housings from a plane modified to support a large concave grating; (4) parts of a gyroscope together with a surplus microscope converted to a comparator; (5) cannon connectors adapted to lens holders; (6) components of a sniperscope and electronic equipment integrated into a demonstration and detection equipment for infrared radiation; (7) a machine shop optical projector used as a spectral comparator; (8) magnetron magnet built into eddy current pendulum and Barlow wheel; and (9) a production vacuum tube machine converted into a spectrometer table.

3. Demonstration of the oscillatory discharge of a condenser. Kenneth V. Manning, *The Pennsylvania State College*.—A variable condenser, inductance, and variable resistor were connected in a series circuit. The condenser was charged periodically through a rotating contact. During the ensuing interval the condenser discharged through the circuit, and the form of the discharge was shown on an oscilloscope connected across the condenser. The apparatus consisted of five 2-μf condensers, the 800-turn coil of a dissectible transformer, and a dial resistance box. The rotating contact was a brass piece set into a Bakelite disk made to fit the shaft of a motor. Two metal fingers rode on the disk to make the contact. The effect of changing capacitance, inductance, or resistance was readily shown. Since the time of discharge was constant, the number of loops was an indication of the frequency of the discharge. With minimum resistance the capacitance or inductance could be changed (inductance changed by inserting an iron core), the number of loops decreasing as each factor is increased. The effect of resistance was shown by the increased damping as the resistance was increased even to the point that there was no oscillation and the curve of discharge through a high resistance was obtained.

4. Three demonstration experiments. Eric M. Rogers, *Princeton University*.—(*i*) *Impulsive force when landing after a jump*.—A lump of clay represented a man landing on a floor without bending his knees. The floor was pivoted and attached to a spring balance which showed the huge maximum force involved. (*ii*) *Microscopy with transparent objects: how the observer may be deceived or helped.* A glycerine thumbprint on glass was used as an object in a simple projection microscope with an illuminated slit as source. The image was made visible by using dark-field illumination, central dark-field, and *schlieren* illumination. With full illumination the image was invisible unless misfocused. The demonstrations led to a discussion of phase microscopy. (*iii*) *A chain reaction without mousetraps*. Half-inch steel balls were arranged in rows on a sloping plank of Lucite. A single moving ball started a chain reaction when the slope was sufficiently steep, illustrating ionization by collision or any other chain reaction.

5. Optical refraction and Fermat's principle. Richard Schlegel, *Michigan State College*.—The derivation of the optical law of refraction on the basis of Fermat's principle is customarily made by determining the condition under which the time of light passage over some variable path length takes a stationary value. An alternative derivation which utilizes the Weierstrass-Erdmann corner condition of the calculus of variations was here presented. This condition states that, subject to certain restrictions, a minimizing or maximizing function $f(x, y, y')$ must satisfy the equation $\partial f^+/\partial y' = \partial f^-/\partial y'$ at a corner of an arc, where f^+ and f^- are the values of the function on opposing sides of the corner. Snell's law follows from the corner condition, as an immediate consequence of a requirement on the behavior of a light ray at a point rather than on the behavior over a finite interval.

6. A nodal slide of flexible design for a course in intermediate optics. Leonard Eisner, *The Pennsylvania State College*.—The nodal slide utilizes the fact that the image of a distant object does not shift laterally when an optical system is rotated slightly about an axis through the second nodal point. The present design reverses the usual procedure and locates this point by moving the axis, keeping the optical system longitudinally fixed. Thus the image remains focused. A standard optical bench is mounted on a flat carriage which pivots about a rod in a base plate; the rod slides in a groove in this plate, and can be clamped in any position. The length and sturdiness of the optical bench allow one to use systems that would be difficult to study on other nodal slides. For example, a telephoto lens can be set up with principal points far in front of the lens elements, or the effect on the cardinal points of using water instead of air as the second medium can be studied. The instrument, which was shown, can be used for qualitative demonstration or for quantitative laboratory measurements.

7. A mechanical demonstrator for Fermat's principle. W. Cullen Moore, *Boston University*.—The law of parsimony is particularly applicable in teaching physics to science as well as nonscience students. Such a philosophy soon embraces the principle of a "least potential energy

state" for explaining the behavior of closed physical systems. However, the study of Euler's and Hamilton's principles and other similar relationships is frequently left as an advanced mathematical exercise, and the many applications are not tied together. Fermat's "least time" (actually "extremum") principle in optics is of the same family and serves to express the fundamental behavior of light as expressed in the specific examples of specular reflection and Snell's refraction law. From the same type of considerations one can also show the behavior of electrical systems as expressed in Ohm's law. Such an approach has been used successfully to describe the behavior of radio waves propagating long distances over the earth when the path configuration does not lend itself readily to geometrical analysis. In this study it became advisable to construct a mechanical model to simulate the ray paths and also to serve as a computer having good relative accuracy. The principle of "least potential energy" is used in the model to produce mechanical effects which have a one-to-one correlation with the "least time" effect under investigation. The result is a simple demonstration experiment which can be constructed from string and pulleys for the presentation of both the mechanical and optical counterparts of the general theory. This paper presented briefly the theoretical background of the Least Time Simulator and reviewed some of the applications of the general theory. The objective of the model was defined and its construction and calibration were discussed. A short motion picture showed the construction details of the simulating computer, its operation for the analysis of radio ray paths over the earth to a moving high altitude rocket, its reliability, and its accuracy. The finished model is well suited for classroom demonstrations.

8. Fresnel diffraction demonstrated with a ripple tank. H. D. RIX, *The Pennsylvania State College.*—A number of features of Fresnel diffraction can be demonstrated advantageously with a ripple tank.[1] For the single-slit case, the slit width may readily be varied from as little as one wavelength up to any width desired. With a one-wavelength slit the approximately circular wave fronts falling off in amplitude with increasing obliquity are observed, and the absence of minima, as predicted by simple theory, is verified. With wider slits the maxima and the minima in the central part of the field, as well as the minima and secondary maxima in the region of geometrical shadow, can be observed and the amplitudes measured. In treating double-slit diffraction, it is convenient to employ slits three or four wavelengths in width and examine the effect of varying the separation of the centers. If for any of these cases, the amplitude distribution is calculated from the Cornu spiral, reasonably good agreement is found with the experimental data for both the positions and approximate relative amplitudes of maxima and minima. Other diffraction phenomena that can be exhibited include the field due to a straight edge and the maximum along the axis in the shadow of a small obstacle. An important advantage of the ripple tank method is that, since a large part of the field is observable at one time, instead of a single-field position as in optics, the development of the pattern in space can easily be studied.

[1] Part of this work was done under Contract No. W 36-039 sc-32001, U. S. Army Signal Corps Engineering Laboratories, Bradley Beach, N. J.

9. Uses of television techniques in demonstration apparatus. H. W. FULBRIGHT, *Princeton University.*—Some uses of a wired television system as a lecture-room aid were shown. The pictures appeared on a viewing tube 30 in. in diameter. The use of the system in connection with small-scale phenomena was particularly emphasized.

10. A demonstration gyroscope. V. E. EATON, *Wesleyan University.*—The wooden rim of a bicycle wheel is replaced by a 20-lb brass ring and the resulting rotor mounted in gimbals to make a gyroscope with three degrees of freedom. This gyroscope is supported by a table equipped with casters. The table is displaced and rotated to demonstrate the operation of a directional gyro and a heavy ball is mounted on one end of the axis to show precession. If the degree of freedom around the vertical axis is suppressed and the table rotated, the gyroscope sets itself with its axis of spin parallel to the axis of rotation, as in the case of a gyroscopic compass. If, however, the axis of the gyroscope is constrained by a pair of springs, the position of the axis depends upon the rate of rotation and the apparatus becomes a turn indicator. To illustrate the ship stabilizer the gyroscope frame is supported on a pair of wheels and stabilized with a pair of springs. Since the frame is statically stable, the gyroscope should be statically stable and this is accomplished by attaching a heavy ball to the lower end of its axis. If the supporting springs are removed, the frame becomes a statically unstable monorail car and dynamic stability is obtained by making the gyroscope statically unstable. By using a wooden bowl as a three-dimensional rocker, the gyroscope may also be used as an artificial horizon.

11. Some servo-mechanism principles. T. A. BENHAM, *Haverford College.*—A brief explanation was first given of the operation of the selsyn and of the graph of the torque *versus* angular displacement. The differential equations of the selsyn with very light damping, with heavy frictional damping, and with acceleration damping were presented. The Laplace transform of the last-mentioned differential equation was written and Routh's criterion applied to determine whether there were real positive roots and thence instability of the system. Advantages and disadvantages of the various available methods of obtaining stability were described. The effects on the stability and accuracy of the system of varying the parameters were demonstrated through the use of a pair of selsyns.

12. Architectural physics. WILL V. NORRIS, *University of Oregon.*—To reorient senior students in architecture to the basic principles of physics, the University of Oregon introduced some years ago a course in architectural physics, to be given concurrently with the work in the mechanical accessories to buildings, which covers plumbing, heating, ventilation, electric wiring, illumination, and acoustics.

This new course contains the basic physical principles required for an understanding of these various subjects. It provides a review of their college physics and introduces such new material as necessary for a satisfactory understanding of the physical relationships in the mechanical accessories to buildings. The paper contained details of the course, type of examinations, qualification of instructors, method of presentation, and references used. The course now consists of one lecture per week for 32 weeks, to a class of about 50 students.

13. A unified approach to physics. NOEL C. LITTLE, *Bowdoin College*.—Breaking with the usual compartmentalization into mechanics, sound, heat, light, electricity and magnetism, followed by modern physics, it is proposed to organize all fields of physics in terms of five fundamental concepts: length, time, force, quantity of electricity, and temperature. In the first part of the elementary course these concepts are introduced *seriatim* together with selected topics to make their nature clear: for example, geometric optics with length, kinematics with time, statics of a rigid body with force, electrolysis with quantity of electricity, and thermometry and calorimetry with temperature. The second part of the course is organized on the basis of five types of phenomena which cut horizontally across the usual subdivisions. First, energetics introducing the concepts of work, kinetic energy, the first law of thermodynamics, and types of energy associated with the topics are taken up in part one. Dynamics, the second law of thermodynamics and the mass-energy relation of relativity find a place here. Second, flow phenomena stress the parallelism of the steady flow of water, heat, and electricity. Third, field phenomena show how the inverse-square law applies alike to gravitation, electro- and magnetostatics, radiation, and photometry. Fourth, periodic phenomena starting with the kinematics of uniform motion in a circle and simple harmonic motion, deal with waves of all kinds. Fifth, quantum phenomena deal with the nature of the elemental particles and the indeterminancy principle. This approach makes for economy in presentation and stresses the unity of physics.

14. A preprofessional undergraduate curriculum in physics. STANLEY S. BALLARD, *Tufts College*.—The several avenues leading toward a bachelor's degree with a major in physics include the following: The regular liberal arts major, which is given in perhaps 400 American colleges and universities; a physics major taken under the general engineering curriculum which is now available in many engineering schools; and an engineering physics or industrial physics curriculum which is offered in some engineering schools and universities. The last-mentioned is enjoying the fastest growth, with perhaps 50 institutions now offering this curriculum of "applied physics in an engineering atmosphere," as it has been called. No one of these is as satisfactory as would be a special curriculum designed for physics majors and leading to a "Bachelor of Science in Physics" degree. This would have a similarity to the parallel situation in chemistry which has been operating for ten years or more and has resulted in the accreditation by the American Chemical Society of the chemistry curriculum in over 150 colleges and universities. The possible advantages of this new curriculum over the standard curricula noted above were discussed—advantages which should accrue to the student, to the college physics department, and to the profession of physics. The essential features of the proposed curriculum were briefly outlined. It is believed that this curriculum should be able to provide proper undergraduate preparation for graduate work in physics, for junior industrial research and development positions, or for junior technical and scientific positions in government laboratories. Such a special preprofessional undergraduate curriculum should do much to strengthen the profession of physics and its growing professional consciousness, and should be of great advantage when the time comes for the establishment of more formal professional standards in physics.

15. Curricula for physics majors. W. C. KELLY, *University of Pittsburgh*.—A program for undergraduates majoring in physics may well provide: (1) intensive training for a few very able students who will do graduate work in physics and (2) less-specialized training for a greater number of students who will choose other professions, e.g., medicine, but who want the background that undergraduate work in physics can give them. As planned at the University of Pittsburgh, the curriculum for the first, or professional, group aims at thorough preparation for graduate work and is based partly on a survey of current practice throughout the country. The curriculum for the second group is characterized by greater flexibility to meet the variety of interests represented. Students in this group may substitute courses in applied physics for the more difficult courses of the senior year. The author described the curricula and commented briefly on the scope of the physics courses included.

16. Foreign language for the undergraduate. G. K. SCHOEPFLE, *Kent State University*.—In order to advise properly undergraduate physics students on the needs for foreign language in graduate study and in industry, two investigations have been made. The requirements were determined of the 54 graduate schools having 25 or more students in physics and it was found that in roughly half of these there is no language demand for the master's degree. While practically all institutions still require two languages for the doctorate, many institutions permit languages other than German and French. The recognition of Russian is noted both among the graduate schools and in industry. Along with information requested for another purpose, the need of foreign language was raised with 33 corporations of varying fields in which physicists are employed. There are extremes of opinion, but 7 corporations feel that foreign language supplies an essential part in the training of young physicists.

17. The physics instructor in the laboratory. LOUIS R. WEBER, *Colorado Agricultural and Mechanical College*.—The laboratory can be the most important phase of a general course in physics. However, Kruglak[1] recently

stated: "One of the weak links in the teaching of college science is the untrained, unprepared, and often unsupervised teaching assistant!". Many of our new physics instructors with advanced degrees have inadequate laboratory experience as undergraduates or graduates under capable professors. This combination is most valuable. Realizing the tremendous variation in experience possessed by new personnel, a laboratory instructor's manual is in preparation for our staff, to be used by the individual or in-service training groups for the general physics laboratory. This manual would attempt to do for the laboratory instructor what Strong's[2] and Sutton's[3] books accomplish in their respective fields. The first chapters will include the various aspects of conducting a good laboratory from the proper attitude to the fine art of "looking over a student's shoulder." The second part discusses specific experiments commonly used; optimum operation of instruments involved; common causes of equipment "failure." Suggestions for encouraging capable students to engage in creative thinking and experimenting are included.

[1] Haym Kruglak, *Am. J. Physics* **17**, (27) 1949.
[2] John Strong, *Procedures in experimental physics* (Prentice-Hall, 1942).
[3] Richard Sutton, *Demonstration experiments in physics* (McGraw-Hill, 1938).

18. Present trends in university courses in general physics for premedical students. E. L. Harrington, *University of Saskatchewan.*—A discussion was given of the various factors which have led to the present rather rapid spread in courses in general physics particularly suitable to the needs of premedical or of biology students. Many large universities are among those giving such courses. It is found that such students give a better response to the work than was formerly accorded to the standard, engineering-type course. Many liberal arts students choose the new-type course in preference to the old. The type of material found suitable for the newer course was illustrated by a few examples.

19. A criticism of the contemporary physics textbook. A. V. Bushkovitch, *St. Louis University.*—The current textbooks of first-year college physics suffer from excessive length, 700 or 800 pages of text being quite common. This situation is apparently caused by three factors: The desire to include a large amount of modern physics, the inclusion of much material from applied physics, and a diffuseness of style traceable to a desire to make things easier for the student who is the victim of the continually deteriorating secondary-school standards. As a result, the text assumes the proportions of a reference book and cannot be read by the student in the time which he has at his disposal. It becomes necessary to omit large portions of the text, but the selection of topics to be omitted is not an easy task, and cannot be done properly by the student himself or an inexperienced instructor. Thus the student relies more and more on lecture notes, and uses the book merely as a collection of problems. Physics is essentially a symbolic system, describing the world of experience, and consisting of definitions, laws, and techniques for deducing consequences from these definitions and laws, together with descriptive material which makes them plausible (i.e., the experimental basis of the entire structure). It was suggested that it is this logical structure that should be emphasized, at the expense of all extraneous material, if the student is to receive maximum aid in mastering the principles of the subject.

20. Enthalpy and thermal transfer. Austin J. O'Leary, *The City College of New York.*—To get away from the untenable idea of "flow of heat" which implies a fluid, thermal effects can be accurately described in terms of enthalpy and thermal transfer. A calorimetric definition of enthalpy satisfying a law of conservation of enthalpy for chemical systems at constant pressure, at constant volume, and at variable pressure and volume to the extent that $\int p dV$ can be neglected is first utilized. Internal energy of a $p-V-\theta$ system is defined initially for isobaric change of state by the equation

$$\Delta U \equiv \Delta H - p\Delta V \tag{1}$$

and for isovolumic change by $\Delta U \equiv \Delta H$. From these special definitions, plus specification that dU be an exact differential in the coordinates, an explicit definition of internal energy of any $p-V-\theta$ system in terms of the coordinates and measurable coefficients of the system is obtained. Finally, integration of Eq. (1) for H subject to the single condition that it be conserved for chemical systems at constant pressure gives the accepted thermodynamic expression for enthalpy of a $p-V-\theta$ system in terms of U, p and V $H \equiv U + pV - (U_0 + p_0V_0)$. Conservation of this quantity in case a gas at constant volume is part of system or surroundings can be taken care of by choosing the system so that p stands for the pressure on the outside of the container, not variable gas pressure inside.

21. Derivation of thermal emittance equation. A. D. Power, *Tube Department, Radio Corporation of America.*—The total thermal emittance ϵ_t of a test surface is sometimes computed from the equation, $\epsilon_t = (T_b^4 - T_r^4)/(T_t^4 - T_r^4)$, where T_t is the absolute temperature of the test surface during measurement, T_r is the temperature of the measuring thermopile and its surroundings, and T_b is the temperature of a blackbody which, under the same conditions of measurement used for the test surface, produces the same thermopile indication. The derivation of this equation was given, together with the assumptions upon which the derivation depends. The more complicated forms which the equation may take when it is assumed that either the comparison body or the thermopile is not a perfect blackbody were also described.

22. World trends in the publication of physical research 1938–1948. John J. McCarthy, *Rutgers University.*—Tables showing the number of abstracts by countries were prepared from the 1938 and 1948 volumes of *Science Abstracts*, Section A. Analysis of these tables indicates: (1) A decrease in the number of abstracts in electricity and magnetism, heat, optics, radiation and spectra, thermodynamics, and x-rays. (2) An increase in the number of abstracts in atomic and molecular structure, cosmic rays,

radioactivity, nuclear disintegration and nuclear particles, vibrations and acoustics. (3) India and Japan in 1938, and India alone in 1948, were the only countries outside of Europe and North America with an appreciable number of abstracts. (4) In 1948 Japan and Poland had no abstracts credited to them while Germany and Italy show decided losses from their 1938 standings. (5) The United States was in second place in the number of abstracts in electricity and magnetism in 1938, third in 1948, and tied for first place in x-rays in 1938. With these exceptions the United States led all other countries in both years. The standings in 1948 reflect the aftermath of World War II: In the defeated countries the publication of research results has decreased, probably due to the emigration of physicists and the shortage of funds. Higher costs and governmental sponsorship of research have tended to reduce the gains in the victorious countries.

23. Illustrated definitions. ROBERT S. SHAW, *The City College of New York.*—Selected cartoons illustrating physics topics were shown. This selection consisted of several, each of which parallels a standard definition of a physical concept. The concepts range from mass to molecule, from angular acceleration to Avogadro's number.

24. Chladni figures or vibrational design. FREDERIKA BLANKNER, *Adelphi College.*—The Chladni figures reveal laws of vibrational design that, when restated in higher dimensional, psychological terms may well be universally applicable to the process of creativity, thereby providing a key to the understanding of art creation, and by means of physics integrating arts, sciences and ethics in numerous new joint-fields.

25. Factor analysis and tests of hypotheses concerning ability in physics. GARLAND D. KYLE, *A M & N College of Arkansas.*—The purpose of this investigation is to (1) find a formula for the regression of ability in physics on certain basic correlated abilities, (2) determine the orthogonal components of physics ability from the correlated abilities, (3) test certain hypotheses concerning group differences with respect to the correlated and uncorrelated subabilities of physics ability, and (4) stimulate a series of investigations for the further determination of the factors of physics ability for larger groups than herein demanded. In this investigation, the writer gave tests in the following abilities to a group of students in first-year college physics: reading, elementary algebra, elementary geometry, scientific information, mechanical aptitude, and perserverance. From the intercorrelation matrix of these tests three principal factors of physics ability were determined and interpreted. The null-hypothesis concerning physics ability of boys and that of girls was tested. Two other hypotheses, namely that concerning equal abilities of the two sections taught and that of whether these groups were matched with respect to general intelligence, their intelligence scores on an outstanding psychological being available. Fisher's discriminant function and Hotelling's T were used in making the tests of significance. Some uses of these procedures may be listed as follows: (1) matching students on certain basic characteristics to test the relative efficiency of two proposed teaching methods or laboratory procedures, (2) testing the different effects on the groups established by method (1), and obtaining the generalized distance which the groups are apart with respect to the spaces determined by the factors or the subtests. From the relative factor loadings, emphasis may be placed on the subtests with the largest factor loadings and on the factors which have been well interpreted and contributed significantly to the total variance of scores.

Report of the Secretary

The Executive Committee of the AAPT met in the American Institute of Physics Building on Feb. 2, from 7:00 P.M. to 2:00 A.M., Feb. 3.

The following were present at the meeting: H. A. Barton, *Vola P. Barton, C. E. Bennett, *D. M. Bennett, *O. Blackwood, *L. Bockstahler, *R. B. Brode, *J. W. Buchta, H. L. Dodge, *R. C. Gibbs, *C. A. Hodges, E. Hutchisson, *Paul Kirkpatrick, K. Lark-Horovitz, *T. H. Osgood, C. J. Overbeck, *R. R. Palmer, *W. L. Parker, *R. F. Paton, *W. B. Pietenpol, *O. L. Railsback, *E. M. Rogers, *Duane Roller, F. W. Sears, *F. G. Slack, *O. H. Smith, *D. L. Soltau, M. H. Trytten, Wallace Waterfall, B. B. Watson, Marsh White, J. G. Winans, and M. W. Zemansky. Asterisks indicate the names of members of the Executive Committee, who were privileged to vote. Others were present by invitation or because of special reports which were to be given. It will be noted from the above list that an unusually representative group was present to act on the business of the Association.

Previous to the meeting your secretary had requested and received reports from the Association's committees and regional section representatives. Most of these reports gave clear evidence of vigorous activities throughout the entire association. Complete details of all these cannot be included in this report but many of them are published in the *American Journal of Physics* when of general interest and significance. Members desiring more information may address requests to the secretary of the Association.

Highlighting the business of the session were two items. The first concerning joint activities with the American Institute of Physics. It was agreed that 15 percent of the annual dues for 1951 should be paid to the American Institute of Physics as is done by each supporting member society. Our representatives on the governing board of the American Institute of Physics are: P. E. Klopsteg, 1948–51; Paul Kirkpatrick, 1949–52; H. K. Schilling, 1949–52; and F. G. Slack, 1950–53. These members have been nominated by the members of the Association at appropriate annual elections.

After lengthy discussion and careful consideration of the finances of the Association, it became evident that a free subscription to *Physics Today* for the entire membership could not be given for 1950 without raising the dues to the members. It was voted that three months subscription

be given each regular member. Subsequently the director of the Institute very generously agreed to allow those so desiring, to continue their subscription for the remainder of the year for $3.00. It was further agreed that a letter explaining these details should be mailed to the entire regular membership of the Association.

The second item of business which demanded a large portion of the time of the seven-hour session was the discussion of the new constitution, the need for which had been evident for several years as the membership and activities of the Association grew. Paul Kirkpatrick, past president of the Association, presented the report of the committee concerned with this revision and members of the entire executive committee, all of whom had received copies prior to the meeting, contributed many constructive suggestions. The content and the wording of this new constitution and by-laws were presented at the general business session on Saturday morning, Feb. 4. It was here voted to mail preliminary copies to the regular members before submitting it for final approval or rejection. The reason for this procedure was to give each member an opportunity to suggest amendments before being asked to vote on the adoption. The committee on the revision very generously consented to continue to function until a final vote could be taken.

A brief summary of other items of business transacted by the Executive Committee follows.

The treasurer's report and that of the auditor was presented and accepted. A favorable balance was indicated.

A budget for 1950 was adopted similar to that of 1949 except for the one large item of additional expense involved in financing the three months subscription to *Physics Today* voted for the Association members by the Executive Committee.

On recommendation of Editor Osgood, F. T. Adler, University of Wisconsin; G. F. Chew, University of California; and J. W. McGrath, Kent State University of Ohio, were appointed as Associate Editors of the *Journal* for a three-year period, replacing those whose terms had expired.

The membership committee reported that the number of members on the roll now totaled over 3100.

The representatives of the Association cooperating with the ACE, the AAAS, the NSTA, and the ASEE were present and gave reports showing progressive and worthwhile activities.

Several other committees reporting were continued, realigned, or discharged as having completed their work.

Among those discharged were the "Coulomb's Law Committee," whose final report is now published, and the Cooperative Committee on Science and Mathematics Teaching. This latter committee was discharged on recommendation of its original sponsor K. Lark-Horovitz who has promoted the activities so vigorously and effectively for many years. It was his feeling that our representative on the AAAS committee would be adequate to continue this important function of the AAPT.

The L. W. Taylor Committee has entered on a new and more specific task and further development will appear shortly as plans are developed.

The Visual Aids Committee is working out a plan with the McGraw-Hill Company for producing a number of short motion picture studies on elementary topics in physics.

At the business meeting Saturday morning new officers for 1950 were announced by the tellers.

President: Duane Roller.
Vice President: Mark Zemansky.
Executive Committee: F. W. Sears; J. G. Winans.

Attendance at the various sessions ran from an estimated 500 to never less than 200.

The conveniences and courtesies extended by Barnard College were greatly appreciated and an enthusiastic vote of thanks was passed at the business session.

All members present were equally enthusiastic about the possibility of meeting at Barnard in 1951. This meeting is already being planned. No previous meeting is planned,[1] though a summer three-weeks "work-shop" for teachers of physics was suggested and may be arranged if sufficient interest to justify such a meeting develops.

The only other future meeting of special interest to members is one planned for October, 1952. The Executive Committee voted to join in a 20th anniversary meeting of the American Institute of Physics. Active plans for this meeting, to be held in Chicago, are now being formulated and the American Association of Physics Teachers will probably plan special and joint sessions with the other sponsoring societies at that time.

R. F. Paton
Secretary

[1] Since the Secretary's Report was written a Summer Meeting has been planned at Wesleyan University, Middletown, Connecticut, June 20–22, 1950.

Annual Report of the Treasurer

Balance brought forward from December 31, 1948		$ 1,001.72
Cash Received		
Dues received from AIP—Oct. 1 to Dec. 31, 1948	$7,854.03	
Dues received from AIP—Jan. 1 to Sept. 30, 1949	7,852.50	
Refund from AIP for excess of remittances over estimated costs	343.95	
Royalties	352.87	
U. S. Treasury Bond Interest	350.00	
Refund by bank on account of error, bond interest	1.22	
Sale of AJP Directory	1.00	
Total deposited from January 1, to December 31, 1949		16,755.57
Total cash available*		$17,757.29
Disbursements		
Payments to American Institute of Physics		
For *American Journal of Physics* publication**	$4,488.55	

Charges for collection of dues and other services#	1,030.50	
15% of dues collected in 1948 for support of AIP	1,794.47	
President's Office	67.58	
Secretary's Office	856.44	
Treasurer's Office	83.04	
Editor's Office	2,078.76	
Annual Meeting	249.59	
Program Committee	21.90	
Membership Committee	1,381.45	
Dues for American Council on Education	100.00	
Richtmyer Memorial Lecture Honorarium	100.00	
Payment for Associate Editor's Services in 1948	500.00	
Total disbursed		12,752.28
Balance on hand December 31, 1949		5,005.01

The Association held at December 31, 1949, U. S. Government Treasury Bonds and Notes having a par value of $15,000.00

PAUL E. KLOPSTEG
Treasurer

* AIP contribution for membership in the American Council on Education in the amount of $100 for 1949 will be received.
** Includes $501.02 for operations of AJP in 1948.
\# Includes $285.54 for miscellaneous services in 1948.

I have audited the books of account and records of Dr. Paul E. Klopsteg, Treasurer of the American Association of Physics Teachers, for the year ended December 31, 1949, and hereby certify that the foregoing statement of receipts and disbursements correctly reflects the information contained in the books of account. Receipts during the year were satisfactorily reconciled with deposits as shown on the bank statements, and all disbursements have been satisfactorily supported by vouchers or other documentary evidence. U. S. Government Bonds and Notes of $15,000 par value are held in safekeeping by the State Bank and Trust Company of Evanston, Illinois, and a certificate was obtained from the custodian as of December 31, 1949.

WILLIAM J. LUBY
Chicago, Illinois. *Certified Public Accountant*

Report of the Editor for the Year 1949

The year 1949 was the second in which nine issues of the *American Journal of Physics* were published. The average size of the numbers was considerably larger than during 1948 when there had been an increase in the number of issues without any corresponding increase in the number of contributions. In 1949, the total number of pages published was 590, the largest number published during any one year in the *Journal*. A chart showing the growth of the Association and of the *Journal* is given in Fig. 1.

During the year, 100 articles were published in the Regular Section with an average length of 4.86 pages. There were 20 brief items under the heading of Notes and Discussion, each averaging a trifle under one page. Forty-nine Letters to the Editor covering 28 pages were contributed. Among all these items there were 32 that came from outside the boundaries of the United States. This is quite a large proportion when one considers the relative numbers of physicists within and without the United States. The reason is, I believe, that the *American Journal of Physics* is a journal that is unique in its scope.

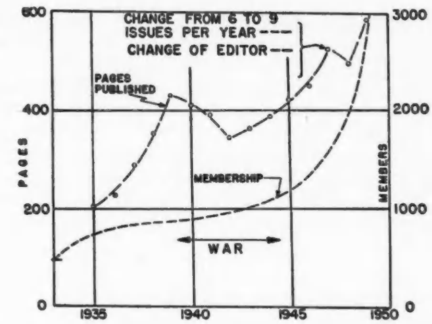

FIG. 1. Growth of membership of the AAPT and increase in the number of pages published in the *American Journal of Physics*, 1935–1949.

The circulation of the *Journal* has increased noticeably with the increase in membership of the American Association of Physics Teachers. In October, November, and December, 1949, 5000 copies were printed each month. Of course, not all these are immediately distributed; some are held for future sale.

Two innovations made during 1948 have already justified themselves. A very considerable number of book reviews has been published and even a casual reader of these will recognize that their quality is high. In this respect, we believe that the *Journal* has performed a useful service to the members of the Association. Reviews are published, however, only of books that seem to have a direct appeal to teachers of physics. Because of this limitation, many volumes that come to the Editor's Office must, of necessity, receive no mention.

The second innovation was a Letters to the Editor column. On a few topics, letters and rejoinders have come briskly and the number of subjects covered has been gratifyingly wide. The Editor wishes to emphasize, however, that the subjects of Letters to the Editor need not necessarily deal with difficult matters of physics, but may deal with any aspect, no matter how general, of the teaching of physics and of the profession. It is hoped that the members of the Association will take this information to heart and will communicate with the Editor if they are in the midst of any problems that are of more than a local nature. A writer of a letter is sure to find that he has a sympathetic audience somewhere who understands his problems and the efforts he is making to solve them.

A great deal of the responsibility for the preparation of manuscripts in their final form for the printer has fallen upon our Assistant Editor, Dr. B. H. Dickinson. The Association may count itself fortunate in having so able and conscientious a man in this position.

During 1949, all the Journals published by the American Institute of Physics, except the *American Journal of Physics* and *Physics Today*, changed to a more economical format than they had been using previously. Our *Journal*

still keeps its original format; *Physics Today* has a format of its own.

Since the Executive Committee of the Association, questioned by mail ballot, could reach no definite conclusion on the matter of switching to the new, more economical format, the Editor polled a sample of 365 members of the Association by mail in the months of December, 1949 and January, 1950. Members were asked to return a prepared post card after indicating their agreement with one of the following statements:

1. I feel strongly that the *American Journal of Physics* should adopt the new format as soon as possible.
2. I do not mind whether the *Journal* adopts the new format or retains its present format.
3. I feel strongly that the *Journal* should retain its present format.

The markings of the questionnaire gave the following count: No. 1, 53; No. 2, 129; No. 3, 25.

It is, therefore, recommended[1] that the new format be adopted as soon as reasonably possible, perhaps on January 1, 1951.

Three Associate Editors concluded their terms of office on December 31, 1949. They were P. S. Epstein, H. A. Nye, and Harold K. Schilling. Upon these gentlemen and the other Associate Editors fell the difficult task of advising the Editor as to which manuscripts submitted for publication should be accepted and which rejected. I am sure that the membership, in general, is unaware of how many helpful comments are made by our Associate Editors which are ultimately incorporated (without formal acknowledgment, of course) in published manuscripts. The Association is indebted not only to these Associate Editors but to a large number of individual members who have been kind enough to appraise papers at the Editor's request.

In place of the three retiring Associate Editors, the following physicists are recommended to the Executive Committee for appointment for the three-year term, 1950–52: F. T. Adler, University of Wisconsin; G. F. Chew, Radiation Laboratory, University of California; J. W. McGrath, Kent State University.

The Editor wishes to place on record his continuous debt to the staff of the Publication Office at the American Institute of Physics, and to the Officers of the American Association of Physics Teachers who have never been too busy to give full consideration to any of the problems of the *Journal* upon which their advice has been requested.

THOMAS H. OSGOOD
Editor

[1] This recommendation was rejected by the Executive Committee at its meeting on 2 February, 1950.

New Members of the Association

The following persons have been made members or junior members (*J*) of the American Association of Physics Teachers since the publication of the preceding list [*Am. J. Physics* **18**, 165 (1950)].

Abraham, George, 2808 Erie St., S.E., Washington, 20, D. C.
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Clingan, Mortimer James, Newberry College, Newberry, S. C.
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Sister Mary Robert Grandfield, Trinity College, Washington 17, D. C.
Sister Rose Margaret Cook, Loretto Heights College, Loretto, Colo.
Skatrude, Rayfield R., Valders, Wisc.
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(*Continued from page 301*)

Harvard University Summer Program Cont'd

program will have the opportunity to choose from three of the General Education science courses: "The Development of Physical Theory from Copernicus to Einstein" (offered by ASSISTANT PROFESSOR GERALD J. HOLTON); "The Philosophy of Modern Science" (by PROFESSOR PHILIPP FRANK); and "Human Behavior" (by PROFESSOR B. F. SKINNER).

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